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DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

WATER-SUPPLY PAPER 426

SOUTHERN CALIFORNIA FLOODS OF JANUARY, 1916

BY

H. D. McGLASHAN AND F. C. EBERT

Prepared in cooperation with the
STATE OF CALIFORNIA

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SOUTHERN CALIFORNIA FLOODS OF JANUARY, 1916.

By H. D. McGlashan and F. C. Ebert.

INTRODUCTION.

The rains that swept southern California in mid-January, 1916, converted the streams into torrents that overran their banks and devastated wide areas of the most fertile land of the State. The rains were heaviest and the floods most disastrous in San Diego County, but they were also very heavy in parts of Riverside, San Bernardino, Los Angeles, and Ventura counties, and they wrought widespread ruin throughout the region that extends southward from Santa Clara River to the Mexican boundary, and westward from the north-south ranges of San Bernardino and San Diego counties to the ocean.

For nearly a month San Diego County was practically cut off from communication with the rest of the State. Fortunately the wireless could be used even after all telegraph and telephone lines failed, and supplies urgently needed at San Diego were brought in by steamer.

Aside from the loss of life, the most serious loss was that resulting from the destruction of the results of the work of generations on well-developed farm lands and their improvements. Dams that are broken down, bridges that are washed out, water mains, pipe lines, irrigation ditches, wells and pumps, and power plants that are damaged can be speedily repaired if funds are available, but it requires a long time to efface completely the track of a flood in a fertile, intensively cultivated river valley.

A record of the magnitude of such a flood and a study of the damage done and of the history of previous floods are of value not only in efforts to solve the general problem of flood prevention, but also in planning the complete utilization of the water resources of a region. In San Diego County, especially, where the losses were very heavy, a number of feasible reservoir sites have not been developed because the expense is apparently not yet warranted by the demand for their utilization for water supply alone. A detailed study may show, however, that the value of these sites as reservoirs for flood protection is sufficient to justify the county in assuming part of the cost of con-

struction or assessing it against the properties to be protected. A fundamental requirement for this study is a knowledge of precipitation and stream flow, such as that presented in the records given in the following pages.

The records of precipitation have been collected by the United States Weather Bureau and many private parties at 156 stations fairly well distributed throughout the area. The records of stream flow have been collected by the United States Geological Survey and cooperating parties, and these also include many records furnished by private individuals. The importance of these records to engineers who are charged with the duty of designing and building structures along these streams is obvious and is impressively emphasized by the magnitude of the floods studied and the enormous destruction they have wrought.

The engineer will be impressed with the fact that whereas damages to property resulting from failure of engineering structures may be evaluated as a basis for determining the limit of economic cost of such structures, the loss of life can not be evaluated. Structures whose safety involves human life should, therefore, be designed much more securely than those whose failure would involve damage to property only.

ACKNOWLEDGMENTS.

It is a distinct pleasure to acknowledge the cordial assistance rendered the writers by engineers, public officials, officers of various companies, and all others of whom such assistance was requested.

All stream-gaging work of the United States Geological Survey in California is done in cooperation with the State Department of Engineering, W. F. McClure, State engineer, and the State Water Commission, W. A. Johnstone (president), Irving Martin, and A. E. Chandler, commissioners.

The section of the report relating to flood run-off would have been much less complete and accurate if it had lacked the data and assistance furnished by Mr. W. S. Post, consulting engineer for the Volcan Land & Water Co. and the Cuyamaca Water Co. During the floods and in the weeks following these companies made a very strong effort to collect all information possible, and they also placed special parties in the field at different times to obtain such additional data as the writers desired to complete and check parts of the records. The chief engineer of the Sweetwater Water Co., Mr. John F. Covert, furnished a number of valuable flood records which he had carefully collected, and Messrs. G. S. Strout, E. R. Bowen, and C. H. Lee obtained stream measurements and furnished very helpful information regarding the floods on the San Luis Rey. The list would be long if mention were made of

all parties who cooperated. Specific acknowledgment is made in connection with the detailed records.

All published and unpublished records of the United States Weather Bureau in the area covered by this report were furnished through Mr. G. H. Willson, section director, San Francisco. The local offices at Los Angeles and San Diego also furnished much detailed information. Records collected by private parties are acknowledged in connection with data for the stations. The Los Angeles County records were furnished by Mr. J. W. Regan, engineer of the flood-control district.

Estimates of the amount of damage to property were furnished as follows:

Assessors: Montgomery M. Moulton, San Diego County; James Sleeper, Orange County; C. B. Bayley, Riverside County; E. J. Gilbert, San Bernardino County; Ed W. Hopkins, Los Angeles County.

County engineers and surveyors: George Butler, San Diego County; J. L. McBride, Orange County; A. C. Fulmor, Riverside County; J. A. Sourwine, San Bernardino County; and F. H. Joyner, Los Angeles County, road commissioner.

City engineers: George Cromwell, San Diego; J. M. Oakey, San Bernardino; Clarence E. Bayley, Pomona; R. V. Orbison, Pasadena; Homer Hamlin, Los Angeles; Albert de Ruiz, Long Beach; and Chas. E. Chambers, president board of trustees, San Jacinto.

Railway engineers: A. Ervast, chief engineer, San Diego & South Eastern Railway Co., San Diego Electric Railway Co.; E. J. Kallright, general superintendent, San Diego & Arizona Railway Co.; W. J. Gough, superintendent, Los Angeles & San Diego Beach Railway Co.; J. McMillan, general manager, Pacific Electric Railway Co.; Arthur Maguire, chief engineer, San Pedro, Los Angeles & Salt Lake Railroad Co.; J. Q. Barlow, assistant chief engineer, Southern Pacific Co.; R. B. Ball, engineer Grand Division, Atcheson, Topeka and Santa Fe Railway Co.

Water company engineers: John F. Covert, chief engineer, Sweetwater Water Co.; F. M. Faude, assistant manager, Cuyamaca Water Co.; J. B. Dixon, superintendent, Escondido Mutual Water Co.; Francis Cuttle, president, Riverside Water Co.; W. S. Post, consulting engineer, Lake Hemet Water Co.; H. R. Case, manager, Temescal Water Co.

Miscellaneous: F. H. Tolle, secretary and general manager, South Coast Land Co.; R. C. Starr, hydraulic engineer, Pacific Light & Power Corporation; H. W. Dennis, construction engineer, Southern California Edison Co.; C. O. Poole, chief engineer, Southern Sierras Power Co.; Austin B. Fletcher, State highway engineer; J. L. Ord, division plant superintendent, Western Union Telegraph Co.; C. L. Lewis, superintendent, Postal Telegraph-Cable Co.; D. P. Fullerton, general superintendent of plant, Pacific Telephone and Telegraph Co.; L. M. Klauber, superintendent electric department, San Diego Consolidated Gas & Electric Co.; L. M. Drown, manager, Western Salt Co.; T. L. Barnes, general manager, Fenton-Sumption-Barnes Co.; C. R. Olberg, U. S. Indian Office; Maj. G. B. Pillsbury, Corps of Engineers, U. S. Army.

The loss of life was reported by the following coroners: Dr. Otto G. Marsh, San Diego County; Theo. A. Winbigler, Orange County; C. S. Dickson, M. D., Riverside County; J. L. McMinn, San Bernardino County; and the coroner's office of Los Angeles County.

PRECIPITATION.

STORMS OF JANUARY, 1916.

The storms from which the floods of January, 1916, resulted began January 17, but light rains had been reported for several days preceding. The United States Weather Bureau [1] described the storms as follows:

> It seems reasonable to suppose that the storm which swept over Hawaii on the 18th–19th passed inland over California on the 27th. It is charted as Low No. XIV, Chart III. About a week previous Low No. X, Chart III, passed inland over the middle California coast on the 17th, crossed the south-central part of the State on the 18th, and then moved northeastward into Wyoming by the morning of the 19th. During its movement over the south-central portion of California the storm slackened its progressive movement, meanwhile giving very heavy rains over the counties of southern California. Light rains had fallen during the previous three or four days and conditions were unusually favorable for a high run-off in connection with the heavy rains of the 17th and 18th. * * * The resulting floods were severe and much damage was done to railroads, bridges, highways, land under cultivation, and to the harbor of Los Angeles, by reason of the mass of silt deposited thereon.
>
> A second deluge of rain descended upon the counties of southern California in connection with Low No. XIV, mentioned in a preceding paragraph. The second storm was of much shorter duration. At San Diego, Cal., the rain began at 7.18 p. m. of the 26th and ended at 7.45 p. m. on the 27th. The total fall amounted to 2.41 inches. This rainstorm was attended by unusually high winds for southern California, the average velocity at San Diego being about 30 miles per hour, with a maximum of 54 miles from the south at 4.29 a. m. of the 27th. The reservoirs in the county whence the water supply of the city of San Diego is drawn were already nearly full as a result of the rains of the previous week, and all of them, evidently, were not in a condition to withstand the added strain put upon them by the rains of the 26th–27th.

The table on pages 12–16 contains records of precipitation not only at stations maintained by the Weather Bureau, but at many other stations maintained publicly or privately in the basins described in this paper. A few records obtained in adjoining river basins have been added for purposes of comparison and indicate the limits of excessive precipitation during the two storms. (See Pl. I, in pocket.)

From the records presented in these tables the mean precipitation for the principal drainage basins in San Diego County has been computed for the period covered by the storms. Records for these basins were collected at 63 stations fairly well distributed throughout the region. The stations were plotted on the map (Pl. I), and lines of equal precipitation were drawn. The boundary of each drainage basin above selected points was also indicated, and the areas between adjacent precipitation lines within each basin were measured with a planimeter. The results are given in the following table:

---

[1] Monthly Weather Review, vol. 44, No. 1, January, 1916.

Mean precipitation in drainage basins in San Diego County, Cal., for period Jan. 14 to 30, 1916.

Station.	Drainage area.	Mean precipitation.
	Square miles.	*Inches.*
Otay River at Lower Otay dam	98.6	19.2
Jamul Creek above Lower Otay reservoir	69.8	21.0
Sweetwater River at Descanso	43.7	27.4
Sweetwater River at Sweetwater dam	181	21.8
San Diego River at diverting dam	102	27.6
San Diego River at Lakeside	203	25.0
San Diego River at Mission dam	375	21.4
San Diego River at San Diego	434	19.9
San Vicente Creek	74.9	19.2
Santa Ysabel Creek near Mesa Grande	53.4	30.3
Santa Ysabel Creek near Ramona	110	25.8
San Dieguito River at Carroll dam site	299	23.6
San Dieguito River at mouth	[a] 340	22.4
Santa Maria Creek near Ramona	57.3	21.2
San Luis Rey River near Mesa Grande	209	24.9
San Luis Rey River near Nellie	240	25.4
San Luis Rey River near Pala	322	25.7
San Luis Rey River at Bonsall	465	24.3
San Luis Rey River at Oceanside	565	22.6

[a] Approximate.

In the mountainous part of the area much of the precipitation was in the form of snow, as shown by the following table, in which the amount of snow on the ground on January 15 is compared with that remaining January 31:

Snowfall, in inches, in mountains of southern California for January, 1916.[a]

Station.	Total snowfall.	Amount on ground on 15th.	Amount on ground on 31st.	Compared with normal.
Bear Valley dam	36	4	30	+ 9
Converse Nursery	46	3	6	.....
Holcomb	80	22	36	+59
Squirrel Inn	41	20	27	+32
Seven Oaks	36	.....	.....	+22
Nellie	21	0	6	.....
Julian	15	7	1	.....

[a] Willson, G. H., Climatological data, California section, January, 1916, p. 11.

Precipitation, in inches, at stations in southern California, for January, 1916.

Station.	No. on Pl. I.	Elevation (feet).	Day of month.																Total for period.	Total for month.	Authority.
			14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30			
Tia Juana basin:																						
Barrett dam	101	1,600	1.21	2.30	0.64	4.45	3.30	1.04	0.88	.....	.....	.....	.....	0.16	0.38	1.60	4.75	0.05	0.60	21.36	21.91	San Diego.
Campo	102	2,543	2.35	1.17	4.75	2.23	1.20	1.23	.....	.....	.....	.....	.....	.....	.55	1.83	4.35	.10	.38	20.14	20.44	U. S. Weather Bureau.
Morena reservoir	103	3,010	.....	3.10	.98	5.13	4.65	1.62	1.33	.05	.....	.....	0.02	.21	.40	1.97	6.13	.10	.54	26.23	28.09	San Diego.
Otay basin:																						
Dulzura summit	104	1,300	1.94	.67	3.22	4.58	.88	1.01	.....	.....	.....	.....	.09	.34	2.20	9.90		.62	.....	25.45	26.75	Do.
Jamul ranch	105	800	.....	3.65	3.80	2.35	.61	.....	.....	.....	.....	.....	.....	.....	.....	6.65		1.48	.....	18.54	20.53	Do.
Jamul store	106	1,050	.74	.74	3.00	3.60	.....	.86	.....	.....	.....	.....	.....	.75	2.00	3.86		1.18	.....	16.73	17.76	Do.
Lower Otay reservoir	107	490	.....	.48	.46	1.86	1.82	.53	.45	.....	.....	.....	.....	.02	.15	1.12	2.25		.25	9.39	9.91	U. S. Weather Bureau.
Sweetwater basin:																						
Alpine Heights	108	1,800	1.56	.78	4.76	3.27	1.29	.50	.....	.....	.....	.....	.....	.63	2.75	5.45	.12	.50	.....	21.61	22.90	J. F. Covert.
Bonita	109	110	.65	Tr.	.50	1.48	2.16	.58	.41	.....	.....	.....	.....	.04	.14	1.26	2.10	.43	.....	9.75	10.29	U. S. Weather Bureau.
Descanso	110	3,350	.....	2.09	1.00	6.50	4.80	1.65	.....	.....	.....	.....	.....	.....	.....	11.00		.....	.....	27.04	29.42	C. H. Ellis.
Descanso ranger station	111	3,500	.....	2.12	1.02	6.36	4.98	1.33	.67	.....	.....	.....	.02	.38	.73	3.11	7.07	.09	.80	28.68	30.67	U. S. Forest Service.
Green Valley	112	4,100	2.30	.05	2.96	6.17	2.91	.85	.....	.....	.....	.....	.....	1.46	.22	6.48	2.04	.38	.51	26.33	28.13	J. F. Covert.
Sweetwater dam	113	300	.45	.11	1.10	1.10	1.51	.46	.38	.....	.....	.....	.....	.07	.15	2.87		.....	.35	8.55	8.97	Do.
San Diego basin:																						
Boulder Creek	114	2,700	1.10	.48	4.20	3.10	2.85	3.75	.60	.56	.....	.....	.....	.30	.68	4.70	3.36	.60	.....	26.28	31.51	Cuyamaca Water Co.
Chocolate	115	750	.45	1.22	.71	4.13	2.87	1.35	.65	.....	.....	.....	.....	.06	.45	1.22	5.19	.....	.34	18.64	19.81	Do.
Cuyamaca, East	116	4,680					13.28								10.30				.....	23.58	26.85	Do.
Cuyamaca reservoir	117	4,677	1.20	.72	3.35	5.83	5.27	1.59	.....	.....	.....	.03	.23	1.63	1.53	8.54	1.30	1.12	.....	32.34	36.50	U. S. Weather Bureau.
Diverting dam	118	820	.60	1.11	.69	3.80	3.30	.53	.53	.....	.....	.....	.....	.23	.27	1.64	5.20	.10	.27	18.14	19.25	Cuyamaca Water Co.
El Cajon	119	482	.52	.46	1.86	4.41	1.24	.60	.....	.....	.....	.....	.....	.26	.05	5.60	.74	.10	.25	16.09	16.68	U. S. Weather Bureau.
El Cajon, Sweetwater Pass	120	670	.41	.60	.66	3.11	3.31	.60	.49	.....	.....	.....	.....	.08	.23	.19	4.00	.....	.24	15.71	16.49	Cuyamaca Water Co.
Grossmont	121	650	.....	.70	.64	2.50	.76	.....	.....	.....	.....	.....	.....	.12	.32	1.94	3.48	.....	.....	10.46	11.24	Do.
Julian	122	4,220	Tr.	1.58	.95	5.95	6.49	1.73	1.36	.....	.....	.....	.06	.19	1.31	3.31	7.68	.35	.58	31.54	35.85	U. S. Weather Bureau.
Lakeside	123	410	.85			7.36			.....	.....	.....	.....	.....	.20		5.30		.18	.....	13.89	14.42	J. H. Beadle.
La Mesa reservoir	124	510	.....	.65	.55	2.36	.56	.....	.....	.....	.....	.....	.....	.12	.....	1.56	3.32	.04	.33	9.49	10.13	Cuyamaca Water Co.
Los Coches	125	700	.....	1.14	.84	2.52	2.45	.55	.60	.....	.....	.....	.....	.09	.33	1.05	3.15	.18	.....	12.90	13.56	Do.
Miramar ranch	126	600	.50	.20	.45	3.75	1.75	1.45	.....	.....	.....	.....	.....	.55	.35	5.20	.70	.....	.30	15.20	16.20	Miramar ranch.
Pine Hills	127	4,900	1.09	.80	3.39	7.08	4.10	1.45	.....	.....	.....	.....	.13	.94	.64	7.80	1.60	.25	.60	29.87	33.74	Cuyamaca Water Co.
Point Loma	128	302	.08	.62	.37	.80	2.10	.93	.70	.....	.....	.....	.01	.15	.14	2.14	1.27	.03	.23	9.57	10.09	U. S. Weather Bureau.
San Diego	129	87	.53	.09	.95	1.55	.31	.80	.....	.....	.....	.....	Tr.	.21	.22	2.19	.06	.17	.....	7.08	7.56	Do.
Shillings ranch	130	4,600	.....					17.50									19.00			36.50	40.01	Cuyamaca Water Co.
San Dieguito basin:																						
Carroll dam site	131	270	.17	.33	.41	2.83	2.57	.71	.28	.....	.....	.01	.....	.49	.38	5.07		.....	.32	13.57	14.94	Volcan Land & Water Co.
Escondido	132	657	.52	.36	2.00	4.85	1.95	1.06	.....	.....	.....	.....	.....	.71	.08	5.53	.58	.50	.11	18.25	19.55	U. S. Weather Bureau.
Mesa Grande (Angel)	133	3,900			20.00				.....	.....	.....				11.00				.....	31.00	33.60	Volcan Land & Water Co.
Mesa Grande (Davis)	134	3,430	.87	.60	3.26	8.08	3.99	.10	.....	.....	.....	.....	.17	1.19	.34	8.55	1.63	.33	.65	29.76	33.28	U. S. Weather Bureau.

Pamo dam site	135	820		.91	.63	5.55	3.40	1.55	.71					.35	.36	1.81	6.10	1.05	.40	22.82	24.47	Volcan Land & Water Co.
Ramona (Sentinel)	136	1,440	.43	.40	1.90	4.90	1.55	1.40						.30	2.45	5.15	1.30			19.78	21.59	Do.
Rose Glen	137	2,800	1.05		.70	5.14	4.65	1.58	.71			.35		.70	5.87	1.52	.60			22.87	24.62	Do.
San Pasqual	138	450		.50	2.20	2.20	1.70	2.25				.50		1.58	4.30	1.08	.70			17.01	18.32	L. D. Rockwood.
Santa Ysabel divide	139	3,250				20.29						1.69			17.70					39.68	42.51	Volcan Land & Water Co.
Santa Ysabel ranch house	140	2,950				16.25									11.25					27.50	30.40	Do.
Santa Ysabel store	141	2,980	1.34	.87	5.55	5.36	2.03	.67	.34					.83	2.42	6.24	.25	.53		26.43	29.41	Do.
Volcan Mountain	142	4,800		1.40	1.08	8.50	7.02	1.19	2.00					1.00	.90	4.30		9.02		36.41	39.87	Do.
Witch Creek	143	2,800	.85	.65	2.85	6.30	3.65		1.90			.10		.75	.40	6.90	1.45	.30	.50	26.60	29.30	Do.
San Luis Rey basin:																						
Canfield ranch (Bonsall)	144	250			1.90	4.38	.45	1.50	.52					.60	2.00	2.60				13.95	15.33	B. F. Thorpe.
Damron	145	2,720			19.73									1.27		11.69		1.05		33.74	36.87	Volcan Land & Water Co.
Deadmans Hole	146	3,300	.90		5.85	5.35	2.00	.60							4.25	6.00		.90		25.85	27.96	Do.
Eagles Nest	147	4,550				[d]12.50								6.84						19.34	20.40	Do.
Gopher Canyon (Bonsall)	162	300	.50			8.30						.80			4.80		.50			14.90	15.90	Thos. Waite.
La Jolla Indian Reservation.	148	2,715	.46	.22	2.52	7.42	4.00	1.43	Tr.			.10	.57	.52	5.75	1.38	.22	.50		25.09	27.95	U. S. Weather Bureau.
Matagual	149	2,800				14.46									10.22					24.68	27.56	Volcan Land & Water Co.
Mendenhall	150	4,400	1.35	.75	6.30	3.35	2.80					.45		7.25			2.25			24.50	28.32	Do.
Nellie	151	5,350	.42	.51	3.52	11.24	6.00	1.85	Tr.			.19	1.85	.97	10.16	2.27	.85	.28		40.11	44.41	U. S. Weather Bureau.
Oceanside	152	60	.55	.20	1.80	1.23	1.20	.26				Tr.	.54	.08	2.02	1.60	.06	.31		9.85	10.90	Do.
Puerta La Cruz	153	2,800				14.97									7.40					22.37	23.88	Volcan Land & Water Co.
San Luis Rey	163	60		.67	.44	3.80	.75	1.60	.23					.66	.07	4.10	.32	.46		13.10	13.85	B. F. Libby.
Valley Center	154	1,300	.56	.40	4.25	4.15	2.00	.38						.25	.45	2.00	4.95	.45		19.84	21.03	Volcan Land & Water Co.
Warner Dam	155	2,710	1.13	.80	6.37	7.10	2.34	.76				.22	.50	2.70	7.73	.04	1.01			30.70	33.93	Do.
Warner ranch house	156	2,895				12.24							9.10				.50			21.84	24.16	Do.
Warner ranch (Rincon)	157	2,900				19.40									11.03					30.43	33.83	Do.
Warner Springs	158	3,095	.62		2.25	5.08	2.30	1.06				.01	.15	.14	4.42	.77	.26	.28		17.34	18.92	U. S. Weather Bureau.
Warner's Summer Road	159	2,810				18.41									7.12					25.53	27.16	Volcan Land & Water Co.
Temecula basin:																						
Aguanga	201	1,986	.07	1.30	3.00	3.80	1.31								5.00	2.00	.05	.35		16.88	17.85	U. S. Weather Bureau.
Oak Grove	160	2,751		.05	1.20	5.55	2.80	1.60	.10			Tr.	Tr.		7.80	1.20	.18	.37		20.85	22.05	Do.
Santa Ana basin:																						
Anaheim	301	150		.87		2.85	1.93	1.27	.49				.36	.17	2.76	.07	.76			11.53	15.28	Anaheim Sugar Co.
Arrowhead Springs	401	2,000	.27	.12	3.90	2.00	.80	.20				.10	.25	.10	1.90	.60	.08	.45		10.77	13.00	U. S. Weather Bureau.
Bear Valley dam	402	6,700	1.00		8.83	12.92	2.16	.17					.44		10.00					26.52	37.60	Do.
Beaumont	202	2,317	.28	1.52	2.08	2.20	1.71	.70					.56	.67	1.58	2.70	.08	.35		14.43	16.16	Do.
Beaumont (near)	203	2,558	.28	.30		5.95	2.55	.61	.74				.53	.55	2.02	4.18		.63		18.34	21.30	Do.
Camp Baldy	403	3,850			1.50	10.00	9.00	.64						1.80					.84	23.78	25.88	Do.
Chino	404	714		.46	.15	4.80	3.57	1.56	.28				.80	.27		1.75	2.11	.07	.87	16.69	20.53	Do.
Claremont	524	1,200	.02	.38	.07	4.68	4.41	.82	.42	Tr.			Tr.	.61	.16	1.20	2.19		.58	15.54	18.37	Do.
Converse nursery	405	6,000	.12	.05	1.02	6.80	3.64	1.70				Tr.	Tr.	1.24		7.42	1.76	.57	.23	24.55	28.41	Do.
Corona	204	615	.37		.78	4.30	1.96	.87	Tr.				.30	.36	.01	5.00	.25	.46	.05	14.44	17.12	Do.
Craftonville	406	1,750	.15	2.20	1.70	1.00	.50						.50	.30	.70	1.90		.45		9.40	10.85	Do.
Dormans ranch	407	2,500		1.20		13.70			27.63						8.50			1.80		52.83	57.91	Do.

For footnotes see p. 16.

Precipitation, in inches, at stations in southern California, for January, 1916—Continued.

Station.	No. on Pl. I.	Elevation (feet).	Day of month. 14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total for period.	Total for month.	Authority.
Santa Ana basin—Continued.																						
El Casco	205	1,870	.....	.....	.....	3.00	1.25	1.20	0.20	.....	.....	.....	.....	0.36	0.37	1.15	0.08	0.43	.....	8.04	8.91	U. S. Weather Bureau.
Elsinore	206	1,300	0.40	0.22	3.43	2.30	1.40	.45	.....	.....	.....	.....	0.25	.26	1.40	3.40	.02	.21	.....	13.74	14.83	Do.
Fontana	408	1,325	.34	.....	.54	4.21	1.86	1.28	.....	.....	.....	.....	.06	.72	.98	2.98	.....	.55	.....	13.52	17.51	Do.
Glenn ranch	409	3,256	.....	.78	.10	7.02	12.00	1.45	1.65	.....	.....	.....	.....	.05	.....	1.98	3.10	.....	0.70	28.83	32.27	Do.
Hemet Lake	207	4,350	.....	.30	.74	2.75	2.81	.75	.....	.....	.....	.....	.....	.85	.12	3.76	.88	.40	.....	13.36	16.04	Hemet Water Co.
Mentone power house	410	1,900	.21	.....	.14	1.95	2.99	1.40	.....	.....	.....	.....	.30	.30	.80	2.94	.....	.45	.....	11.48	14.02	Pacific Light & Power Corp.
Mill Creek No. 2	411	2,950	.28	.12	2.17	2.88	1.30	.61	.....	.....	.....	.....	Tr.	.99	.12	4.05	.45	.55	.....	13.52	15.95	U. S. Weather Bureau.
Old Ranch	302	90	.....	.42	.10	1.68	.87	.96	.32	.....	.....	.....	.....	.48	.09	2.15	1.50	.62	.37	8.96	10.69	Do.
Orange	303	180	.....	.60	.17	2.42	1.57	.89	.42	.....	.....	.....	.....	.42	.22	2.01	1.32	.04	.30	10.38	13.17	Do.
Pomona	525	840	.....	.50	.05	3.50	4.85	1.05	.55	.....	.....	.....	.02	.60	.35	1.10	2.22	.....	.63	15.42	18.74	Do.
Redlands	412	1,352	.....	.08	.55	3.44	.98	.79	.....	.....	.....	.....	.....	.42	.05	2.31	.48	.07	.38	9.55	10.64	Do.
Rialto (Lytle Creek)	413	2,250	.88	.13	3.04	12.95	2.80	1.37	.....	.....	.....	.....	.51	1.78	1.14	5.34	.....	1.05	.....	30.99	39.76	Do.
Riverside	208	851	.11	.16	2.26	1.15	.61	.51	.....	.....	.....	.....	.28	.43	.65	1.67	.03	.47	.....	8.33	9.66	Do.
San Bernardino	414	1,054	.24	.04	.80	5.29	1.18	1.20	.....	.....	.....	.....	.....	.69	.05	3.16	.14	.53	.07	13.39	15.51	Do.
San Jacinto	209	1,560	.14	.08	1.10	2.78	.96	.82	.....	.....	.....	.....	.....	.55	.....	2.17	.46	.11	.16	9.33	10.71	Do.
Santa Ana	304	130	.48	.14	1.78	1.18	.51	.57	.....	.....	.....	.....	.....	.32	.28	1.62	1.74	.....	.35	8.97	10.98	Do.
Santa Ana River	415	2,850	.74	.06	2.26	9.00	4.00	.....	.....	.....	.....	.....	.....	.....	1.50	6.25	.20	2.00	.....	26.01	30.81	Do.
Seven Oaks	416	5,000	.52	.27	5.60	6.10	3.40	.43	.....	.....	.....	.....	.25	1.00	2.25	6.45	.10	.35	.....	26.72	31.10	Do.
Sierra power house	526	2,250	.....	.83	.10	5.30	9.40	1.33	.....	.....	.....	.....	.....	.46	.08	1.78	3.18	.....	.75	23.21	29.43	Pacific Light & Power Corp.
Squirrel Inn	417	5,280	.48	.45	1.21	c16.81	5.83	3.02	.....	.....	.....	Tr.	.12	.69	.60	7.05	.80	1.60	Tr.	38.66	50.29	U. S. Weather Bureau.
Summit No. 2 (Cajon Pass)	418	3,823	.....	.24	.26	2.35	2.65	.40	.....	.....	.....	.....	.....	.....	.....	1.41	.....	.....	.....	7.31	9.65	Do.
Tustin	305	125	.....	.30	.12	1.75	1.06	.78	.38	.....	.....	.....	.....	.41	.26	1.41	1.68	.07	.43	8.65	9.84	Do.
Yorba Linda	306	405	.....	.....	.52	3.52	1.17	1.17	.....	.....	.....	.....	.....	.40	.....	3.01	.04	.47	.06	10.36	13.68	Do.
San Gabriel basin:																						
Alhambra	501	455	.....	5.40		3.00	1.10	.....	.....	.....	.....	.....	.....	.....	.....	3.00	.....	.40	.....	12.90	17.70	Do.
Arcadia	502	490	.15	.....	.....	5.00	4.00	.56	.....	.....	.....	.....	.....	1.00	.....	1.02	1.60	.50	.....	13.83	16.31	Do.
Azusa	503	540	.01	.30	.02	6.10	4.76	.95	.16	.....	.....	Tr.	Tr.	1.17	.10	1.26	1.57	Tr.	.46	16.86	20.32	Do.
Azusa power house	504	750	.....	.32	.06	5.82	7.47	.70	.27	.....	.....	.....	.....	1.64	.08	1.22	1.97	.....	.43	19.98	23.21	Pacific Light & Power Corp.
Bassett	505	295	.....	.46	.04	3.20	3.00	.72	.50	.....	.....	.....	.....	.45	.08	1.40	1.40	.....	.52	11.77	15.62	U. S. Weather Bureau.
Buena Park	506	77	.....	.60	.09	2.30	1.67	.99	.....	.....	.....	.....	.....	.32	.12	1.68	.77	.90	.....	9.44	13.97	Do.
Camp Bonita	507	2,000	.....	.88	.05	5.18	8.90	1.60	.20	.....	.....	.....	.....	.76	.05	1.54	3.32	.....	.52	23.00	28.74	Do.
Camp Iron Fork	508	3,500	.....	1.12	.....		16.75			.....	.....	.....		4.55			.....	.60	.....	23.02	29.01	Do.
Covina	509	560	.....	.30	4.45	3.65	.70	.....	.....	.....	.....	.....	.75	.....	.....	1.15	1.65	1.53	.....	14.18	16.92	Do.
Duarte	510	550	Tr.	.34	.05	5.20	4.92	.45	.45	.....	.....	.....	.....	1.08	.07	1.18	1.70	.....	.38	15.82	19.16	Do.
El Monte	511	280	.....	.43	.....	4.80	2.62	.67	.15	.....	.....	.08	.50	.....	1.25	1.38	.40	.40	.....	12.68	15.90	Do.
Liveoak Canyon	512	1,500	.37	.05	5.83	5.89	1.01	.....	.....	.....	.....	.....	.76	.14	1.29	2.33	.....	.90	.....	18.57	22.26	Los Angeles County.

Lordsburg	513	1,040				7.40	3.68	.90						.83		3.30			.71	16.82	20.49	U. S. Weather Bureau.
Monrovia	514	550		.32	.05	5.08	4.48	.45	.41				.02	.92	.06	1.13	1.82	.38		15.12	18.46	Do.
Mount Lowe	515	3,420		.30		11.10									3.76					15.16	19.86	Do.
Mount Wilson	516	5,850	.62	.31	.58	6.38	4.37	1.14				.02	.36	.76	.03	4.40	.03	.30		19.30	24.47	Do.
Baldwin Acres	517	385	.33	.05	3.35	1.98	.68	.06					.05	.40	1.25	1.30		.33		9.78	12.74	Los Angeles County.
Norwalk	518	95		.75	.07	2.00	1.45	.72	.25					.50	.10	1.80	.90	.15	.66	9.35	13.50	U. S. Weather Bureau
Pasadena	519	827	.40	.11	.41	4.68	2.47	.75				.01	.04	.54		2.58	.01	.31		12.31	16.45	Do.
San Gabriel	520	415				5.30	2.82	.95								2.35			.39	11.81	15.01	Do.
Santa Anita ranger station	521	1,750		.80	.10			15.40				1.40				No record						Los Angeles County.
Sierra Madre	522	1,400	.37	.10		5.50	3.30	.94				1.20			.10	2.50	.12	.35		14.48	18.74	U. S. Weather Bureau.
Walnut	523	520		.25		6.00		.75				.50				3.00		.50		11.00	14.00	Do.
Los Angeles basin:																							
Arroyo Seco ranger station	527	1,400	.25		.45	5.60	4.07	.91				Tr.	.13	.87		2.50		1.00		15.78	20.89	Los Angeles County.
Compton	528	70		.53	.05	2.02	.78	.60				.06	.07	.56	.07	2.24	.68		.93	8.59	12.54	U. S. Weather Bureau.
Dillon ranch	529	2,220	.20	1.40	1.30	6.20	3.75					.30	.40	1.10	1.30	2.80		.75		19.50	26.30	Los Angeles County.
Empire Canyon	530	3,330		.74		5.70	2.60	.61	.49					1.21		2.10		.50		13.95	18.52	Do.
Grassy Flat	531	3,000		.31		6.00	3.10	.65						.77		2.75		.62		14.20	14.95	Do.
Haynes Camp	532	2,500		.71		5.50	3.00	.49	.88					.79		1.85		.39		13.61	18.23	Do.
Haynes Canyon (mouth)	533	2,250		.71		5.00	2.50	.47						.80		2.20		.40		12.08	12.84	Do.
Littlelands	534	1,800	.05	.80	.04	4.08	3.38	.50	.15		Tr.		.08	.60	.04	1.22	.91	.51		12.36	16.58	U. S. Weather Bureau.
Long Beach	535	25	1.85		.12	1.85	.48	.40	.08			.05		.45	.08	2.80	.58	.07	.28	9.09	12.81	Do.
Los Angeles	536	293	.38	.04	1.07	4.16	.82	.43				.01	.11	.33	.33	2.28		.43		10.39	13.30	Do.
Oneonta ranch	537	1,000		.23	.01	3.15	2.51	.70	.20				.08	.50	.05	.89	1.04		.42	9.78	12.04	Los Angeles County.
Pacoima	538	1,570	.20			4.50	3.05	.57	.15				.10	.55	.05	1.36	1.09	.40		12.02	14.58	U. S. Weather Bureau.
San Fernando	539	975		.29		3.97	2.73	.68					.16		.05	1.62	.61			10.11	13.39	Do.
San Pedro	540	25	1.00	.10	1.00	.40	.50							.40		1.60	.60			5.60	7.80	Do.
Sunland	541	1,400	.34	.05	.25	3.95	2.43	.44						.76		1.99		.34		10.55	12.89	Los Angeles County.
Tropico	542	435	.32		4.75	2.50	.80	.16					.50		1.06	1.40		.38		11.87	14.66	U. S. Weather Bureau.
Wilmington	543	20		.60	.60	1.90	.80	.65					.70	.60		2.20	.70	.05	.40	9.20	13.65	Do.
Coast Basin:																							
Ocean Park	544	10		.30	.02	2.50	1.37	.49	.12				.07	.36		1.23	1.10	.02	.55	8.13	10.72	Los Angeles County.
Santa Barbara		130	.70		.27	3.36	.73	.52				.09	.27	.92		3.10	.76			10.72	.17.24	U. S. Weather Bureau.
Santa Monica	545	110		.69		5.82		.63				.15		.63		2.85		.50		11.27	14.69	Do.
Santa Clara basin:																							
Clearwater power house	a547	2,350	.61			4.40		.30				.17		.25	1.85			50		8.08	11.34	Do.
Newhall	548	1,200	.89		2.00	3.03	1.93	.38				.05				2.67		.43		11.38	15.72	Do.
Ravenna	549	2,470		.20		1.25	1.45	.57	.20							.35	.45			4.47	5.07	Do.
Sespe Camp	(b)	1,500	1.88		.62	5.12	4.08									3.75		.62		16.07	25.00	Sespe Light & Power Co.
West Saticoy	(b)	150	.75		.28	3.00	1.35	.33				.05	.13	.34	1.88	1.88		.25		10.24	14.14	U. S. Weather Bureau.
Ventura basin:																							
Ojai Valley	(b)	900	.80			5.85	2.15	.28					.18	.70		3.95	Tr.	.47		14.38	20.82	Do.
Cuyama basin:																							
Ozena	(b)	3,680	.37		2.80	1.32	.49			.04			.07	.14	.41	1.00	.09	.18		6.91	8.38	Do.
Great basin:																							
Cabezon	210	1,790			.20	4.20	4.60	2.10	2.30						.50	.10				14.00	14.20	Southern Pacific Co.
Coahuila	211	3,800	.16		2.00	2.00	2.25	.50						1.50	1.50	1.50	.25	.60		12.26	14.61	U. S. Weather Bureau.
Fairmont	a549	2,785	.07	.45		2.58	3.07	.52	.09					.13	Tr.	.67	.41	.02		8.01	11.59	Do.
Holcomb	419	7,800	.50		.29	3.72	2.60	.73								1.88	.44	1.50	.30	11.96	13.28	Do.
Nenach	a550	3,000		.25		1.40		.90	.25			.04				.12			.09	3.05	3.70	Do.
Palm Springs	212	680			.30	1.00	1.00	.75	.35							1.00				4.40	5.20	Southern Pacific Co.

For footnotes see p. 16.

Precipitation, in inches, at stations in southern California, for January, 1916—Continued.

Station.	No. on Pl. I.	Elevation (feet).	Day of month.																	Total for period.	Total for month.	Authority.
			14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30			
Great Basin—Continued.																						
San Felipe	161	3,600			14.50				.....	.....	0.20			.....	9.00		0.20		.....	23.90	25.40	Volcan Land & Water Co.
Valyermo	551	3,750	0.08	.....	.20	2.77	1.72	0.39	0.23	.....	.....	.....	.....	.....	.....	0.58	.....	Tr.	.....	5.97	6.31	U. S. Weather Bureau.

[a] Not shown on maps in pocket.
[b] Ventura County, not shown on maps in pocket.
[c] Greatest amount for one day ever recorded in California.
[d] Record is total for period Jan. 9 to 20.

NOTE.—In general, the maximum precipitation for the first storm occurred on January 17 and for the second storm on January 27. Various methods were used in recording the observations. At the regular stations of the Weather Bureau precipitation is recorded for the 24-hour period ending at midnight; at the cooperative stations the observations are made either late in the afternoon, near sunset, or in the morning, and the amount recorded is for the preceding 24 hours. At the stations maintained by private parties the observations are usually made at 7 a. m. and the general practice is to record the amount as the precipitation for the preceding day, although at some stations it is given as the precipitation for the day on which the measurement was made. Station numbers refer to location shown on maps in pocket, as follows: San Diego County, 101-163; Riverside County, 201-212; Orange County, 301-306; San Bernardino County, 401-419; Los Angeles County, 501-551.

RAINFALL IN EARLIER YEARS.

In order that the records of precipitation for January, 1916, may be compared with those of preceding years, complete monthly records of rainfall at San Diego, Los Angeles, and Santa Barbara are given in the following tables. The precipitation for January, 1916, was the maximum for that month recorded at these stations. It was, however, exceeded by the precipitation in February, 1884, at Los Angeles and San Diego, and by that of March, 1867, at San Diego. At Santa Barbara the rainfall of January, 1916, exceeded that of the next highest month, December, 1867, by 36 per cent. See table on page 20.

Precipitation, in inches, at San Diego, Cal., 1850–1916.

Season.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	Seasonal.	Year.	Annual.
1850.....	.....	.....	.....	.....	.....	.....	0	1.13	1.00	0.09	0	0.68	.....	1850	7.84
1850–51...	0	0	0	0.19	2.82	1.93	0.03	1.51	.34	.87	0.71	.01	8.41	1851	7.49
1851–52...	0	0	0.02	.01	.25	3.74	.58	1.84	1.87	.85	.32	0	9.48	1852	11.87
1852–53...	0	0.40	0	.06	1.45	4.50	.50	.20	1.52	.25	2.10	.05	11.03	1853	7.88
1853–54...	0	.21	0	0	1.28	1.77	.99	2.56	1.88	.89	.18	.01	9.77	1854	11.63
1854–55...	0.07	1.36	.09	.27	.04	3.29	1.97	3.59	1.30	1.52	.06	0	13.56	1855	11.15
1855–56...	0	.04	0	.11	2.15	.41	1.27	1.86	1.59	2.17	.29	0	9.89	1856	9.77
1856–57...	0	0	.07	0	1.22	1.30	.26	1.76	0	.04	0.08	.03	4.76	1857	6.15
1857–58...	0	.02	.01	.49	2.16	1.30	1.52	.44	1.24	.17	0	.19	7.54	1858	7.55
1858–59...	0	.04	.10	.47	.28	3.10	0	1.89	.20	.36	.17	0	6.61	1859	6.10
1859–60...	.02	0	0	.18	1.49	1.79	.72	1.49	.15	.65	.04	.05	6.58	1860	9.11
1860–61...	.14	0	0	0	2.88	2.99	.82	.79	.05	.04	0	.19	7.90	1861	7.92
1861–62...	0	0	1.59	.05	1.19	3.20	5.56	1.39	.97	.105	.16	.48	15.64	1862	11.59
1862–63...	.11	0	0	.89	.05	.93	.32	1.09	.33	.13	.02	0	3.87	1863	3.02
1863–64...	0	0	.36	0	.73	.04	.04	2.50	.20	.01	1.25	.01	5.14	1864	7.61
1864–65...	.11	0	0	.04	2.41	1.04	1.28	3.00	0	.56	0	.01	8.45	1865	7.52
1965–66...	1.29	0	0	.02	.52	.84	5.05	3.43	1.47	.11	.09	0	12.82	1866	12.31
1866–67...	0	.10	0	0	.24	1.82	2.32	.85	7.88	.48	.04	0	13.73	1867	15.72
1867–68...	0	.30	0	.34	.45	3.06	3.37	1.63	.73	1.20	.15	0	11.23	1868	11.16
1868–69...	.51	0	.05	0	2.00	1.52	2.88	1.88	1.98	.53	.33	0	11.68	1869	10.96
1869–70...	.05	0	0	.05	2.32	.94	.54	.77	.33	.20	.28	0	5.48	1870	4.37
1870–71...	.04	.07	0	1.54	.18	.42	.52	1.35	.01	.70	.34	0	5.17	1871	5.64
1871–72...	0	0	0	0	1.33	1.39	.99	1.63	.46	.26	.12	0	7.18	1872	5.07
1872–73...	0	.18	0	0	0	1.43	.44	4.21	.11	.10	.03	0	6.50	1873	13.07
1873–74...	0	1.95	0	0	.77	5.46	3.11	3.73	1.20	.34	.32	0	16.88	1874	10.91
1874–75...	.12	0	.13	.53	.88	.55	2.38	.37	.45	.12	.20	.02	5.73	1875	6.80
1875–76...	0	.21	.39	0	2.25	.41	2.47	2.44	1.78	.06	.05	.05	10.11	1876	7.24
1876–77...	.03	.06	.03	.08	.04	.15	1.05	.18	1.44	.26	.43	Tr.	3.75	1877	8.12
1877–78...	0	0	0	.81	.06	3.89	1.45	4.83	1.41	2.91	.58	.16	16.10	1878	13.87
1878–79...	0	0	0	.96	0	1.57	3.54	1.04	.10	.60	Tr.	.07	7.88	1879	14.71
1879–80...	0	0	0	.29	2.77	6.30	.61	1.50	1.43	1.34	.06	.06	14.36	1880	10.37
1880–81...	.09	.32	0	.53	.28	4.15	.52	.45	1.88	1.35	.04	.05	9.66	1881	5.00
1881–82...	0	.01	.04	.24	.12	.30	4.53	2.55	1.02	.45	.18	.07	9.51	1882	9.74
1882–83...	0	Tr.	.01	.41	.39	.13	1.09	.95	.41	.31	1.14	.08	4.92	1883	8.01
1883–84...	0	0	0	2.01	.20	1.82	1.34	9.05	6.23	2.84	2.17	.31	25.97	1884	27.59
1884–85...	0	Tr.	.07	.35	.11	5.12	.35	.02	.78	1.20	.61	.06	8.67	1885	5.73
1885–86...	Tr.	.13	Tr.	.31	1.56	.71	6.95	1.51	3.73	1.95	.04	.07	16.96	1886	15.35
1886–87...	Tr.	Tr.	0	.05	.95	.10	.04	4.51	.02	2.14	.47	.04	8.32	1887	10.45
1887–88...	.01	Tr.	Tr.	Tr.	2.08	1.14	1.96	1.48	2.79	.10	.22	.04	9.82	1888	11.57
1888–89...	.01	Tr.	.04	.26	1.83	2.84	1.72	1.80	2.20	.19	.03	.10	11.02	1889	16.03
1889–90...	Tr.	.04	Tr.	2.12	.12	7.71	2.79	1.70	.41	.05	.08	0	15.02	1890	8.02
1890–91...	0	Tr.	.65	.01	.72	1.61	1.21	4.84	.27	.76	.35	.05	10.47	1891	8.99
1891–92...	Tr.	0	.08	.04	.10	1.29	1.58	2.96	.96	.41	1.15	.13	8.70	1892	9.09
1892–93...	0	.05	Tr.	.22	.91	.69	.78	.47	5.50	.22	.39	Tr.	9.26	1893	10.29
1893–94...	Tr.	0	0	.11	.91	1.91	.29	.49	1.05	.11	.09	.01	4.97	1894	4.35

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Precipitation, in inches, at San Diego, Cal., 1850–1916—Continued.

Season.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	Seasonal.	Year.	Annual.
1894–95	0	0.04	0.01	Tr.	0	2.26	7.33	0.53	1.43	0.11	0.19	0	11.90	1895	11.33
1895–96	0	0	.01	.27	1.19	.27	1.27	.02	2.89	.25	.03	.01	6.21	1896	8.73
1896–97	Tr.	.13	Tr.	.97	.98	2.18	3.13	2.72	1.53	.02	.12	T.	11.78	1897	8.93
1897–98	.01	Tr.	Tr.	1.06	.02	.32	1.71	.06	.91	.22	.66	.02	4.99	1898	4.67
1898–99	0	0	.07	0	.15	.87	2.34	.30	.85	.29	.10	.27	5.24	1899	6.08
1899–1900	0	.07	0	.35	.86	.65	.69	.03	.53	1.26	1.45	.08	5.97	1900	5.77
1900–01	0	Tr.	Tr.	.30	1.43	0	2.08	4.77	1.07	.01	.77	.02	10.45	1901	9.49
1901–02	Tr.	Tr.	.06	.28	.41	.02	1.70	1.57	1.86	.21	.06	Tr.	6.17	1902	11.49
1902–03	.92	Tr.	Tr.	.06	1.53	3.58	.69	2.27	1.17	1.40	.14	Tr.	11.76	1903	6.09
1903–04	0	Tr.	Tr.	.07	Tr.	.35	.04	1.50	2.17	.15	.12	0	4.40	1904	6.61
1904–05	0	Tr.	Tr.	.17	0	2.46	2.16	5.90	2.98	.30	.35	Tr.	14.32	1905	16.36
1905–06	.16	0	.50	.25	3.38	.38	.98	2.62	4.68	.98	.72	.03	14.68	1906	14.90
1906–07	Tr.	.10	.12	.03	.62	4.02	3.27	.45	1.62	.13	.07	.19	10.62	1907	7.95
1907–08	.03	0	0	1.71	.05	.43	2.80	2.41	.61	.35	.16	0	8.55	1908	8.59
1908–09	0	.64	.20	.15	1.00	.27	3.57	1.76	2.62	.02	Tr.	Tr.	10.23	1909	14.14
1909–10	Tr.	Tr.	.02	0	2.39	3.76	2.00	.19	1.30	.08	.05	0	9.79	1910	5.75
1910–11	.01	.05	.17	1.35	.40	.15	3.35	4.92	.92	.65	.01	.01	11.99	1911	11.77
1911–12	.12	0	.10	.28	.02	1.39	.66	0	5.72	2.13	.17	.16	10.72	1912	10.56
1912–13	.14	.26	0	.89	.40	.03	1.19	2.40	.42	.08	.07	.09	5.97	1913	7.30
1913–14	.06	.02	.02	Tr.	2.23	.72	3.59	1.90	.36	.85	.08	0	9.83	1914	10.90
1914–15	0	0	Tr.	1.05	.86	2.21	4.91	3.62	.33	1.15	.28	Tr.	14.41	1915	13.62
1915–16	Tr.	0	Tr.	0	.73	2.60	7.56	.66	.98	.01	.01	Tr.	12.55	1916	11.56
1916–17	.02	.01	.25	.87	.05	1.14	.....	.....	.....	.....	.....	.....	.....	....	.....
Maximum	1.29	1.95	1.59	2.12	3.38	7.71	7.56	9.05	7.88	2.91	2.17	.68	25.97	....	27.59
Minimum	0	0	0	0	0	0	0	0	0	.01	0	0	3.87	....	3.02
Mean	.06	.10	.08	.36	.94	1.80	1.92	1.94	1.46	.62	.31	.06	9.74	....	9.66

Precipitation, in inches, at Los Angeles, Cal., 1877–1916.

Season.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	Seasonal.	Year.	Annual.
1877–78...	0	0	0	0.86	0.45	3.93	3.33	7.68	2.57	1.71	0.66	0.07	21.26	1878	20.86
1878–79...	0	Tr.	0	.14	Tr.	4.70	3.59	.97	.49	1.19	.24	.03	11.35	1879	17.41
1879–80...	0	0	0	.93	3.44	6.53	1.33	1.56	1.45	5.06	.04	0	20.34	1880	18.65
1880–81...	Tr.	Tr.	0	.14	.67	8.40	1.43	.36	1.66	.46	.01	0	13.13	1881	5.53
1881–82...	0	Tr.	Tr.	.82	.27	.52	1.01	2.66	2.66	1.83	.63	Tr.	10.40	1882	10.74
1882–83...	0	0	Tr.	.05	1.82	.08	1.62	3.47	2.87	.15	2.02	.03	12.11	1883	14.14
1883–84...	Tr.	0	0	1.42	0	2.56	3.15	13.37	12.36	3.58	.35	1.39	38.18	1884	40.29
1884–85...	Tr.	Tr.	Tr.	.39	1.06	4.64	1.05	Tr.	.01	2.00	.06	Tr.	9.21	1885	10.53
1885–86...	Tr.	Tr.	Tr.	.26	5.52	1.63	7.72	1.38	2.50	3.29	0	.01	22.31	1886	16.72
1886–87...	0.24	0.21	0	.01	1.18	.18	.20	9.25	.24	2.30	.20	.04	14.05	1887	16.02
1887–88...	.07	0	0.15	.12	.78	2.67	6.03	.77	3.15	.11	.02	Tr.	13.87	1888	20.82
1888–89...	.03	.08	Tr.	.36	4.01	6.26	.25	.92	6.48	.27	.62	0	19.28	1889	33.26
1889–90...	0	.28	.33	6.96	1.35	15.80	7.83	1.36	.66	.22	.03	.02	34.84	1890	12.69
1890–91...	0	.03	.06	.03	.13	2.32	.25	8.56	.41	1.26	.31	0	13.36	1891	12.84
1891–92...	Tr.	0	.06	0	0	1.99	.88	3.19	3.39	.22	2.06	.06	11.85	1892	18.72
1892–93...	0	.01	0	.33	4.40	4.18	6.29	2.27	8.52	.19	.06	.03	26.28	1893	21.96
1893–94...	0	0	Tr.	.75	.20	3.65	.94	.49	.37	.13	.20	Tr.	6.73	1894	7.51
1894–95...	Tr.	.01	.73	.02	0	4.62	5.84	.46	3.77	.46	.19	.01	16.11	1895	12.55
1895–96...	Tr.	Tr.	Tr.	.24	.80	.78	3.23	Tr.	2.97	.19	.30	Tr.	8.51	1896	11.80
1896–97...	.02	.01	Tr.	1.30	1.66	2.12	3.70	5.62	2.31	.02	.10	Tr.	16.86	1897	14.28
1897–98...	Tr.	0	0	2.47	.01	.05	1.26	.51	.98	.03	1.75	Tr.	7.06	1898	4.83
1898–99...	.07	Tr.	.02	.09	Tr.	.12	2.64	.04	1.81	.18	.04	.58	5.59	1899	8.69
1899–1900	0	.01	Tr.	1.59	.90	.90	1.17	Tr.	.99	.54	1.81	Tr.	7.91	1900	11.30
1900–01...	Tr.	Tr.	Tr.	.26	6.53	Tr.	2.49	4.38	.45	.68	1.50	Tr.	16.29	1901	11.96
1901–02...	Tr.	.09	.03	1.88	.46	0	1.62	3.35	2.98	.16	.03	Tr.	10.60	1902	13.12
1902–03...	Tr.	Tr.	Tr.	.40	2.08	2.50	2.10	1.52	6.93	3.77	Tr.	.02	19.32	1903	14.77
1903–04...	0	Tr.	.43	Tr.	0	Tr.	.14	2.68	4.50	.97	Tr.	Tr.	8.72	1904	11.88
1904–05...	Tr.	.17	.28	.69	0	2.45	2.57	6.06	6.00	.35	.95	0	19.52	1905	19.19
1905–06...	0	0	Tr.	.08	2.98	.20	3.85	2.47	7.35	.69	1.02	.01	18.65	1906	21.46
1906–07...	.02	.03	.05	0	.85	5.12	7.02	1.83	4.12	.16	.07	.03	19.30	1907	15.30
1907–08...	0	0	Tr.	1.19	Tr.	.88	5.04	3.66	.18	.52	.25	0	11.72	1908	13.74
1908–09...	Tr.	.08	1.22	.25	1.08	1.46	7.27	5.20	2.51	Tr.	0	.11	19.18	1909	23.92
1909–10...	0	Tr.	.04	.28	1.51	7.00	1.53	.11	1.86	.30	0	0	12.63	1910	4.89
1910–11...	.04	Tr.	.01	.82	.15	.07	6.70	2.91	5.15	.28	.02	.03	16.18	1911	17.85
1911–12...	Tr.	0	1.23	.16	.10	1.27	.07	0	6.99	1.66	.12	0	8.60	1912	9.78
1912–13...	Tr.	0	0	.56	.35	.03	2.01	9.16	.33	.35	.05	.58	13.42	1913	17.17
1913–14...	Tr.	Tr.	.03	Tr.	3.00	1.66	10.35	7.04	.58	.47	.43	.09	23.65	1914	23.91
1914–15...	.01	0	0	.31	.20	3.73	5.42	5.09	.60	.81	.88	Tr.	17.05	1915	16.67
1915–16...	0	0	Tr.	0	1.35	2.52	13.30	1.82	.90	Tr.	.03	0	19.92	1916	23.29
1916–17...	0	Tr.	.77	2.71	.09	3.67									
Maximum	.24	.28	1.23	6.96	6.53	15.80	13.30	13.37	12.36	5.06	2.06	1.39	38.18	....	40.29
Minimum	0	0	0	0	0	0	.07	0	.01	Tr.	0	0	5.59	....	4.83
Mean.....	.01	.03	.14	.72	1.23	2.78	3.49	3.13	2.92	.94	.44	.08	15.78	....	15.92

Precipitation, in inches, at Santa Barbara, Cal., 1867–1916.

Season.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	Seasonal.	Year.	Annual.
1867–68...	a0.02	a0.01	0	0	2.31	12.67	3.97	2.00	1.08	2.44	0.72	0	a25.22	1868	15.72
1868–69...	0	0	0	0	1.25	4.26	3.26	2.12	4.22	.46	.20	0	15.77	1869	11.78
1869–70...	0	0	0	0.30	.65	.57	.25	5.87	.83	.99	.74	0.07	10.27	1870	11.47
1870–71...	0	0	0	1.04	.27	1.41	.86	2.92	.02	2.02	.37	0	8.91	1871	14.67
1871–72...	0	0	0	.09	1.83	6.56	2.53	1.81	.18	1.80	0	.14	14.94	1872	10.87
1872–73...	0	.02	.05	0	0	4.34	.58	5.48	.05	0	0	0	10.52	1873	11.64
1873–74...	0	0	0	0	.27	5.26	4.54	3.17	.78	.28	.14	0	14.44	1874	12.12
1874–75...	0	0	0	1.91	1.30	0	14.84	.18	.38	.10	0	0	18.71	1875	22.34
1875–76...	0	0	0	0	6.53	.31	7.56	5.67	2.73	.27	0	0	23.07	1876	16.55
1876–77...	0	0	0	.32	0	0	2.72	0	.82	.18	.45	0	4.49	1877	8.61
1877–78...	0	0	0	0	1.32	3.12	7.17	11.73	2.47	3.34	.29	.07	29.51	1878	30.55
1878–79...	0	0	0	.32	0	5.16	5.24	.71	.34	1.60	.21	0	13.58	1879	14.70
1879–80...	0	0	0	.41	1.62	4.57	1.30	10.86	1.15	5.73	0	0	25.64	1880	29.30
1880–81...	0	0	0	.25	.28	9.73	2.83	.30	1.25	.59	0	0	15.23	1881	8.16
1881–82...	0	0	.44	1.47	.33	.95	1.13	2.38	5.74	1.63	0	.20	14.27	1882	12.32
1882–83...	0	0	0	.37	.77	.10	2.18	2.92	3.64	.29	2.79	.35	13.41	1883	16.25
1883–84...	0	0	0	1.32	0	2.76	6.33	9.68	9.77	2.60	.39	1.62	34.47	1884	38.82
1884–85...	0	0	0	1.02	.79	6.62	1.23	.07	.35	3.00	0	0	13.08	1885	17.15
1885–86...	0	0	0	.19	9.84	2.47	5.12	1.19	2.03	3.40	0	0	24.24	1886	13.86
1886–87...	0	0	0	.39	.87	.86	.31	8.64	.13	1.43	.33	.03	12.99	1887	17.09
1887–88...	0	0	.38	.31	1.10	4.43	10.15	1.30	3.86	.16	.02	Tr.	21.71	1888	26.80
1888–89...	Tr.	Tr.	.03	.07	5.62	5.59	.29	1.29	7.31	.49	.76	.13	21.58	1889	32.77
1889–90...	0	0	0	8.65	3.21	10.64	5.32	2.96	1.10	.31	.18	.06	32.43	1890	15.49
1890–91...	0	0	1.50	.05	.48	3.53	.45	7.92	1.56	1.57	.30	0	17.36	1891	14.38
1891–92...	0	0	.15	0	0	2.43	1.10	2.55	2.95	.46	1.12	0	10.76	1892	19.37
1892–93...	0	0	0	.26	4.27	6.66	4.41	3.10	7.80	.38	.09	0	26.97	1893	19.61
1893–94...	0	0	0	.82	.07	2.94	.99	.76	.29	.24	.91	0	7.02	1894	10.09
1894–95...	.12	Tr.	1.36	.68	.07	4.67	6.25	.67	1.99	.46	.02	.05	16.34	1895	11.69
1895–96...	Tr.	0	0	.55	.77	.93	6.84	0	2.37	1.78	.08	.05	13.37	1896	18.87
1896–97...	.40	0	0	.92	3.51	2.92	4.35	3.65	2.73	.02	0	0	18.50	1897	12.19
1897–98...	0	0	0	1.44	0	0	.63	1.39	.28	Tr.	1.25	0	4.99	1898	7.22
1898–99...	Tr.	0	3.17	.14	0	.36	4.48	0	2.78	.64	0	.78	12.35	1899	15.06
1899–1900	0	0	0	2.06	1.97	2.35	2.32	.05	1.58	.42	1.90	.01	12.66	1900	10.50
1900–01...	.02	Tr.	.04	.15	3.99	.02	4.86	3.65	.16	2.07	.34	.10	15.40	1901	15.27
1901–02...	.06	.09	.36	2.42	1.16	Tr.	1.36	4.40	2.89	1.40	.07	0	14.21	1902	17.85
1902–03...	0	0	0	1.48	4.01	2.24	2.06	1.63	6.12	2.91	.27	.02	20.74	1903	13.06
1903–04...	0	0	Tr.	Tr.	.05	Tr.	.46	4.69	4.40	1.89	.09	0	11.58	1904	20.82
1904–05...	0	.10	7.15	.51	Tr.	1.53	3.73	8.22	6.40	.51	1.44	.05	29.64	1905	21.93
1905–06...	.18	0	.03	.16	1.14	.07	4.26	3.67	9.96	.83	2.40	Tr.	22.70	1906	27.97
1906–07...	Tr.	.04	0	0	.35	6.46	12.46	2.34	5.64	.27	Tr.	.16	27.72	1907	28.93
1907–08...	0	.03	Tr.	6.23	Tr.	1.80	4.29	5.96	.21	.49	.20	0	19.21	1908	16.83
1908–09...	0	0	1.16	.20	1.84	2.48	15.67	7.92	6.91	0	.03	.08	36.29	1909	43.23
1909–10...	Tr.	.01	.17	.57	2.34	9.53	2.91	.08	3.62	.39	0	0	19.62	1910	10.95
1910–11...	.02	Tr.	2.56	.29	.33	.75	14.21	4.92	7.76	1.02	.03	.05	31.94	1911	30.74
1911–12...	Tr.	0	.12	.28	.02	2.33	.42	0	9.48	2.12	1.58	Tr.	14.35	1912	14.09
1912–13...	Tr.	0	Tr.	.28	.21	Tr.	3.14	6.58	.64	1.04	.19	.50	12.58	1913	18.56
1913–14...	.09	.07	.17	Tr.	3.43	2.71	15.91	7.30	.95	.70	.03	.16	31.52	1914	29.64
1914–15...	.05	0	0	.12	.04	4.38	4.94	8.03	1.15	.97	1.57	Tr.	21.25	1915	21.42
1915–16...	0	0	.05	0	.65	4.06	17.24	1.89	1.71	.30	Tr.	0	25.90	1916	32.19
1916–17...	0	.11	1.90	2.82	.10	6.12	.....	.....	.....	.....	.....	.....	.....	.....	.....
Maximum	.40	.11	7.15	8.65	9.84	12.67	17.24	11.73	9.96	5.73	2.79	1.62	36.29	....	43.23
Minimum	0	0	0	0	0	0	.25	0	.02	0	0	0	4.49	....	7.22
Mean.....	.02	.01	.42	.82	1.42	3.27	4.68	3.56	2.92	1.14	.44	.10	18.64	....	18.60

a Interpolated.

INTENSITY AND DISTRIBUTION OF RAINFALL.

The magnitude of the flood resulting from a given amount of precipitation is determined largely by the intensity of the rainfall and its distribution through the month. The records of the United States Weather Bureau, supplemented by records from private parties, give the information concerning excessively heavy rainfall

at San Diego, Los Angeles, Squirrel Inn, and Campo, which is presented in the following paragraphs:

San Diego.—A self-registering rain gage was installed in San Diego in 1893, but was not in operation during the storms of January, 1916, so that the rate of fall is unknown. The total rainfall recorded from January 15–18, inclusive, was 2.90 inches.

Records collected by William A. Edwards, M. D.,[1] give the following maximum records for 24 hours rainfall:

	Inches.
Dec. 3, 1873, 10 p. m. to night of Dec. 4	2.52
Nov. 9, 1879, morning to 8.10 p. m.	2.75
Dec. 27, 1879, 6 a. m. to Dec. 28, 6 a. m.	2.55
Jan. 12, 1882, 3.50 a. m. to Jan. 13, 3 a. m.	[2]2.49

The heavy rain of December 28, 1896, was the maximum recorded to that date on the self-registering gage and fell at the following rates: 1 minute, 0.19 inch; 5 minutes, 0.32 inch; 10 minutes, 0.47 inch; 1 hour, 0.79 inch.

Records in the San Diego office of the United States Weather Bureau show that on March 15, 1905, the rate of fall was as follows: 5 minutes, 0.32 inch; 10 minutes, 0.41 inch; 15 minutes, 0.58 inch; 30 minutes, 0.74 inch; 1 hour, 0.94 inch; 2 hours, 0.95 inch. A rate of 1 inch in an hour has never been recorded at San Diego.

Los Angeles.—The heaviest rainfall during January, 1916, began at 1.05 p. m., January 16, and ended at 9.30 a. m., January 18; the total for this period was 5.74 inches. From 3.17 a. m. to 3.29 a. m. the rate was as follows: 5 minutes, 0.20 inch; 10 minutes, 0.42 inch,; 15 minutes, 0.46 inch.[3]

Other heavy rainfalls, occurring in 1889, have been reported by the Los Angeles office of the United States Weather Bureau as follows: From December 11, 8 p. m., to December 12, 8 p. m., total rainfall 4.30 inches. From December 24, 8 p. m., to December 25, 8 p. m., 2.72 inches. The rainfall on December 24, from 9.45 p. m. to 10.45 p. m., is estimated at 1 to 1.25 inches.

Squirrel Inn.—The total precipitation from January 14–19, inclusive, at Squirrel Inn, north of San Bernardino, on the south slope of the San Bernardino Mountains, at an elevation of 5,280 feet above sea level, was 27.80 inches, or an average of 4.63 inches for each day. The 24-hour precipitation January 16–17 was 16.81 inches, one of the heaviest for that period of time ever recorded in the United States, and a new record for California.

Campo.—A rainfall of the "Sonora" type occurred at Campo August 12, 1891. The total rainfall for this storm, which lasted more

[1] Reprinted in Littoral California, p. 3, from the Philadelphia Medical Journal, Oct. 11, 1902.

[2] Correct; amount published in Littoral California in error.

[3] Abstracted from United States Weather Bureau Monthly Weather Review, vol. 44, No. 1, p. 57, January, 1916.

than 24 hours, was 16.10 inches, according to Mr. Archibald Campbell, cooperative observer. In a period of about 80 minutes the rainfall was 11.50 inches.

In the following table the daily distribution of rainfall during the month of January, 1916, is compared with that of the months of December, 1889, and February and March, 1884, which were the months of previously recorded maximum rainfall:

Daily precipitation, in inches, for months of maximum rainfall at San Diego and Los Angeles, Cal.

Day.	San Diego.				Los Angeles.			
	December, 1889.	January, 1916.	February, 1884.	March, 1884.[a]	December, 1889.	January, 1916.	February, 1884.	March, 1884.
1	0.94	.....	0.44	.....	1.11	0.60	1.61	.....
2	.....	.....	.43	Tr.	.77	1.07	2.84	Tr.
3	.02	.....	1.52	0.34	Tr.	.....	.45	1.78
4	.12	.....	.65	.17	.11	.17	.29	1.97
5	.....	0.01	.34	.25	.....	.20	.60	1.98
6	.59	.....	.80	.57	.06	.....	.70	.88
7	.10	.....	.16	.09	.37	.....	.62	.18
8	.....	.....	.....	Tr.	.03	.41	.....	.16
9	.52	.20	.....	.79	.46	.29	.....	2.67
10	.....	.27	.37	.15	.....	.17	.49	.05
11	.....	.....	.50	.....	.02	.....	.07	.....
12	.....	.....	.01	.....	4.30	.....	Tr.	.....
13	.14	.....	.....	.....	.59	.....	.....	.....
14	1.18	.53	.12	1.39	.63	.38	.05	1.00
15	1.75	.09	1.35	.35	.72	.04	2.02	.12
16	.07	.95	.96	.....	.....	1.07	1.38	.....
17	.....	1.55	1.31	.....	.....	4.16	2.18	.04
18	.02	.31	.09	.01	.16	.82	.07	Tr.
19	.01	.80	.....	.....	.01	.43	.....	.....
20	Tr.	.....	.....	.....	.01	.....	.....	.....
21	.01	.....	.....	.....	.....	.....	.....	.....
22	.....	.....	.....	.....	1.11	.....	.....	.....
23	1.13	.....	.....	.26	1.61	.01	.....	.05
24	.44	Tr.	.....	.....	1.10	.11	.....	.....
25	.53	.21	.....	.....	2.72	.33	.....	.10
26	.05	.22	.....	.72	.51	.33	.....	.05
27	.03	2.19	.....	Tr.	.....	2.28	.....	.51
28	Tr.	.06	.....	.50	.....	.....	.....	.75
29	.....	.17	.....	.26	.....	.43	.....	Tr.
30	.....	.....	.....	.02	.....	.....	.....	.03
31	.06	.....	.....	.36	.....	.....	.....	.04
Total	7.71	7.56	9.05	6.23	15.80	13.30	13.37	12.36

[a] Total for March, 1867, was 7.88 inches, but daily record is not available; March, 1884, was the next highest.

FLOOD OF JANUARY, 1916.

CREST DISCHARGE.

The heavy storms of January, 1916, fell on ground already saturated, and the water was therefore rapidly carried into the stream channels. Detailed information concerning the discharge of the streams during these storms is given in the run-off records (pp. 40–78) and is summarized in the following tables, which show the crest discharge of the streams and the total run-off compared with the rainfall.

Crest discharges, in second-feet, of streams in southern California for January, 1916.

Station.	Date.	Time.	Gage height (feet).	Drainage area (square miles).	Discharge.	Run-off per square mile.
Cottonwood Creek at Morena reservoir.	Jan. 27	4–6 p. m.		120	15,356	128
Otay River at Lower Otay reservoir.	...do....			98.6	[a] 23,500	238
Jamul Creek near Otay	...do....			69.8	18,100	259
Sweetwater River near Descanso.	...do....			43.7	9,870	226
Sweetwater River near Dehesa...	...do....			112	24,295	217
Sweetwater River at Rudolph ranch.	...do....			135	27,530	204
Sweetwater River near Jamacho.	...do....			172	43,002	250
Sweetwater River at Sweetwater reservoir.	...do....	4.30–5.30 p. m.		181	45,500	251
San Diego River at diverting dam.	Jan. 18	6 a. m.		102	4,710	46
Do	Jan. 28	6 p. m.		102	15,800	155
San Diego River at Capitan Grande dam site.	Jan. 27			189	[b] 36,300	192
San Diego River near Santee.	...do....		25.1	375	70,200	187
San Diego River at San Diego.	...do....	7 p. m.		434	75,000	173
Boulder Creek at Cuyamaca reservoir.	...do....	6 p. m.		12	2,393	199
San Vicente Creek at mouth.	...do....			74.9	18,600	248
Switzer Canyon at San Diego.	...do....	7 a. m.		3.55	668	188
Santa Ysabel Creek near Mesa Grande.	Jan. 17			53.4	10,600	199
Do	Jan. 27	Noon.	11.0	53.4	21,100	395
Santa Ysabel Creek near Ramona.	Jan. 17	9 p. m.		110	14,300	130
Do	Jan. 27	7 p. m.		110	28,400	258
San Dieguito River at Carroll dam site.	...do....	1–3 p. m.	21.2	299	72,100	241
Santa Maria Creek near Ramona.	...do....	5 p. m.	15.9	57.3	7,140	125
San Luis Rey River near Mesa Grande.	Jan. 17	1.45 p. m.	12.8	209	24,400	117
Do	Jan. 27	4.30 p. m.	18.0	209	58,600	280
San Luis Rey River near Pala.	...do....		18.1	322	75,000	233
San Luis Rey River at Oceanside.	Jan. 17			565	40,000	71
Do	Jan. 27	9.30 p. m.		565	95,600	169
Santa Ana River near Mentone..	Jan. 17			189	29,100	154
Santa Ana River at San Bernardino.	...do....				40,000	
Lytle Creek at San Bernardino..	Jan. 18	9.40 a. m.			16,000	
San Jacinto River near San Jacinto.				108	30,000	278
San Jacinto River near Elsinore..	Jan. 28	11 a. m.	19.0	717	14,000	195
South Fork of San Jacinto River at Hemet reservoir.	Jan. 27	4 p. m.		65.8	9,550	145
San Gabriel River near Axusa...	Jan. 18	7 a. m.	12.0	222	40,000	180
Los Angeles River at Los Angeles.					7,268	
Los Angeles River near Dominguez Junction.					31,113	
Arroyo Seco near Pasadena.	Jan. 17	9.30 a. m.	9.3	16.4	3,150	192
Arroyo Seco at Los Angeles.					6,215	
Sespe Creek near Sespe.	Jan. 17		18.7	216	18,600	

[a] Reported by George Cromwell, city engineer, San Diego, (See Engineering News, vol. 75, No. 15, p. 718.)

[b] Mean of two estimates computed from cross sections and slope data.

Summary of run-off of streams in southern California for January, 1916.

Station.	Period (January).	Drainage area (square miles).	Run-off.			Mean rainfall on drainage area January 14 to 30 (inches).
			Total in acre-feet.	Depth in inches on drainage area.	Per cent of mean rainfall.	
Cottonwood Creek at Morena reservoir	1 to 31	120	41,200	6.43	.....	.....
Sweetwater River at Sweetwater dam	16 to 31	181	111,000	11.55	53	21.8
San Diego River at diverting dam	1 to 31	102	92,800	17.06	62	27.6
San Diego River at San Diego	1 to 31	434	213,000	9.19	46	19.9
Boulder Creek near Julian	13 to 31	12	12,300	19.22	.....	.....
Santa Ysabel Creek near Mesa Grande	1 to 31	53.4	66,400	23.29	77	30.3
Santa Ysabel Creek near Ramona	1 to 31	110	104,000	17.75	69	25.8
San Dieguito River near Bernardo	1 to 31	299	257,000	16.14	68	23.6
Santa Maria Creek near Ramona	1 to 31	57.3	33,500	10.96	52	21.2
San Luis Rey River near Mesa Grande	1 to 31	209	141,000	12.68	51	24.9
San Luis Rey River near Nellie	1 to 31	240	165,000	12.91	51	25.4
San Luis Rey River at Pala	1 to 31	322	201,000	11.76	46	25.7
San Luis Rey River at Bonsall	1 to 31	465	257,000	10.36	43	24.3
San Luis Rey River at Oceanside	16 to 31	565	269,000	8.92	39	22.6
South Fork of San Jacinto River at Hemet reservoir	14 to 31	65.8	29,100	8.30	.....	.....
San Gabriel River near Azusa	1 to 31	222	148,000	12.57	.....	.....

CONDITION OF RESERVOIRS DURING FLOOD.

MORENA RESERVOIR.

The Morena reservoir, on Cottonwood Creek 8½ miles upstream from the Barrett dam, has a capacity of 46,000 acre-feet. It forms a part of the municipal water-supply system of San Diego.[1]

The following is a description [2] of the flood of January, 1916, at this reservoir:

The flood brought into the reservoir a large quantity of débris which accumulated in front of the racks that protect the radial gates, and so choked the flow that when the reservoir level was 3 feet above the spillway level the flow actually passing over the spillway beneath the open gates was only 3 inches deep. Under these conditions the water rose within 18 inches of the parapet crest and waves actually carried débris over the top.

Two effects of this pressure are apparent. A downstream movement of the upper face of the dam which showed in the alignment of the parapet as about 2 or 3 inches at the center of the structure, and a settlement of the top of the rock fill amounting to 2 or 3 inches. The amount of leakage could not be observed, but George Cromwell, city engineer of San Diego, who was at the dam during the high water, affirmed that he believed such leakage as there was came through the face of the structure and not around the ends or from beneath. Leakage some time prior to recent storms amounted to 1,500,000 gallons per day.

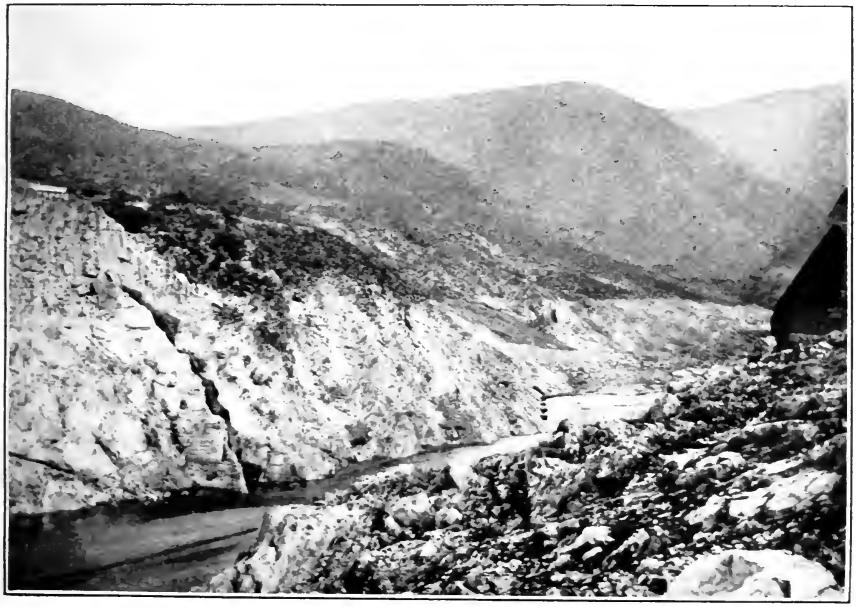
After going down to the bottom of the intake tower during the height of the flood, Mr. Cromwell reported that structure was standing the pressure well, only slight seepage appearing. The intake gates were all in working order and all were left open to lower the reservoir level as much as possible. The débris was being removed by as large a force of men as could be readily assembled. Orders to lower the reservoir 3 feet below the spillway level by means of the intake gates were left at the dam.

[1] O'Shaughnessy, M. M., Construction of the Morena rock-fill dam, San Diego County, Cal.: Am. Soc. Civil Eng. Trans., vol. 75, p. 27, 1913.

[2] Eng. Record, vol. 73, No. 7, p. 228, February 12, 1916.

A. VIEW UP LOWER OTAY RESERVOIR, AFTER FAILURE OF DAM.

Reservoir gage in foreground.



B. VIEW DOWNSTREAM AT SITE OF LOWER OTAY DAM, AFTER FAILURE.

Spillway at extreme left

A. SWEETWATER DAM, AFTER FLOOD OF JANUARY, 1916.

B. BREAK AT RIGHT END OF SWEETWATER DAM, AFTER FLOOD OF JANUARY, 1916.

LOWER OTAY RESERVOIR.

Two reservoirs known as Upper and Lower Otay have been constructed as a part of the water-supply system for the city of San Diego. Upper Otay is at the lower end of Procter Valley and Lower Otay[1] is on the main stream directly south. The capacity of the former is about 3,300 acre-feet; that of the latter about 40,000. Lower Otay dam was overtopped by the flood on January 27, 1916, and destroyed.

The following is a description of the failure of Lower Otay dam by Roy A. Silent:[2]

The rain on January 27 was extremely heavy, and by noon the water had risen so high that Mr. Weuste, in charge at the dam, deemed it advisable to open the outlet gate. This failed to check the rise, and it was realized that the dam would probably be overtopped before evening. Men were accordingly dispatched to warn residents in the valley to move to higher ground. Word to this effect was also sent out from the telephone exchange at National City. Most of the inhabitants took advantage of this warning.

At 4.45 p. m. the water had reached the top of the dam and had seeped through and filled the boxes that were sunk in the top to allow an examination of the steel core. Water began running down the lower face on the east side of the dam at approximately 4.50 p. m. About this time several spouts or small streams of water appeared on the lower face of the dam, in one instance loosening a large bowlder which rolled down to the bottom. From this time on, the destruction was very rapid. The lower face of the fill quickly melted away, thus removing the support from the core wall. At 5.05 p. m. the tension was so great that the steel diaphragm tore from the top at the center, and the dam opened outward like a pair of gates. The released water rushed through and filled the canyon to a point approximately 20 feet below the top of the dam. It required 2½ hours for the reservoir to empty.

A huge wall of water, variously described as from 6 to 20 feet high, rushed down the valley, covering the distance from the dam site to Palm City, about 10 miles, in 48 minutes, carrying all before it. * * *

A thorough examination of the dam site was made on January 31 and February 1. Practically all the fill was washed completely away. The steel core was deposited in varying-sized sections along the valley, a large part being found at Palm City, 10 miles below the dam. The core wall had torn itself loose from both of the side walls, the foundations remaining intact. * * *

Three-quarters of a mile below where the dam had stood a piece of the diaphragm was observed, to which the angle iron forming the bottom of the steel plate was riveted, showing that the extreme bottom had been torn loose. On the west side, behind the remaining core wall, was a small part of the fill, composed of rock of small sizes, none of which was over 1½ feet in diameter and grading from that size to coarse gravel. If this may be considered a fair sample of the remainder of the fill, it is easy to understand its melting away as rapidly as described.

The canyon below the dam, prior to the failure, was considerably restricted and filled with large boulders. The action of the water removed all the loose rock and thoroughly stripped to bedrock both sides of the canyon as high as the water reached, the line of demarcation being clearly defined. The stripping was done in a most thorough manner, no particle of soil remaining in any of the niches or crevasses. This area was heavily wooded with brush. [See Pl. II, *B*.]

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[1] Schuyler, J. D., Reservoirs for irrigation: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 4, pp. 637–640, 1897.

[2] Eng. News, vol. 75, No. 7, pp. 334–336, February 17, 1916.

An interesting feature was observed in that for half a mile below the dam in practically every pocket or niche in the rock was to be found a rivet head. An examination of the remaining parts of the steel core showed it to be in a perfect state of preservation, no rust or corrosion being noticeable. The destruction of the plate for the most part had taken place along the riveted seams, though one or two cases in which the sheets had torn were observed.

Other accounts of the failure have also been published.[1]

SWEETWATER RESERVOIR.

The celebrated Sweetwater masonry dam is on Sweetwater River about 8 miles above its mouth at an elevation of 145 feet.[2]

The following description of the breaks in Sweetwater reservoir was prepared from information supplied by Mr. J. F. Covert, chief engineer, Sweetwater Water Co.:[3]

On January 27 the flow into the reservoir exceeded the combined capacity of spillway and blow-off valves, and the level behind the dam raised until the parapet was overtopped at 2.20 p. m. At 4.30 p. m the flow over the parapet had increased to a depth of 3.5 feet, and the 50-foot length of earth-fill dike at the north end of the structure was overtopped. The water washed away this fill, broke the concrete-core wall, and cut a by-pass around the dam through the bedrock foundation. The break is about 75 feet wide, with a maximum depth of 30 feet below the level of parapet. [See Pl. III.]

This break was made by degrees, no water appearing below the dike until it was actually overtopped, and the cutting into the foundation was gradual. At 7 p. m. the reservoir level was lowered only 0.3 foot. Water flowed over the parapet about seven hours after the break occurred, it is believed, which would mean that the flood continued to overtop the dam for about nine hours.

An earthen dike 650 feet long stood some distance from the dam, where a low point in the ridge occurred. This dike had a puddled-clay core and was 23 feet high at its mid-point. At 3.50 p. m. on the day of the flood peak the water level reached the top of this dike and began to spill over the downstream slope. This melted as the water continued to rise, and when the flood subsided the dike had been swept out cleanly except for about 10 feet of its length. The material on which the dike stood was eroded by the outpouring water to such an extent that the reservoir rim at this point is now 15 feet below the spillway level.

CUYAMACA RESERVOIR.

Cuyamaca reservoir is formed by an earthen dam on Boulder Creek, a tributary of San Diego River. The capacity given by a 35-foot dam is 11,400 acre-feet.[4]

The effect of the flood on this reservoir has been described as follows:[5]

The impending danger of the recent flood was realized in time to draw down the Cuyamaca reservoir considerably. In fact, the amount drawn off by the blow-off

[1] Eng. News, vol. 75, No. 5, pp. 236–239, Feb. 3, 1916; Eng. Record, vol. 73, No. 7, p. 226, Feb. 12, 1916.
[2] Schuyler, J. D., Reservoirs for irrigation: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 4, pp. 669–682, 1897; also details of design and last increase in height, in Eng. Record, Sept. 2, 1911, p. 264.
[3] Eng. Record, vol. 73, No. 7, p. 225, Feb. 12, 1916.
[4] Schuyler, J. D., Reservoirs for irrigation: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 4, pp. 698–700, 1897.
[5] Eng. Record, vol. 73, No. 7, p. 228, Feb. 12, 1916.

valve through the dam was about 1,000,000,000 gallons. The peak of the flood brought the reservoir level up to within 14 inches of the crest of the dam, with both spillways flowing over 4 feet deep. A few washouts on the conduit constituted the only damage suffered by this system, which includes, in addition to the Cuyamaca dam, three smaller reservoirs on tributaries of the San Diego River.

DAMAGE DUE TO FLOOD.

An inventory of the damage in Los Angeles, San Bernardino, Riverside, Orange, and San Diego counties, believed to be practically complete except for minor losses, is given in the following pages. Every effort was made to obtain the best information available, and all public officials, engineers, and others to whom requests were made for estimates regarding losses in their departments or business gave hearty cooperation. A number of the statements were prepared within a few months after the storms, and hence were based upon estimated costs rather than actual expenditures. The loss of life was determined from reports obtained from the coroners of each county. The total direct damage is estimated at about $10,000,000. This estimate is based on the best available information, which is summarized in the following table:

Summary of flood damage in southern California January, 1916.

Character of damage.	San Diego County.	Orange County.	Riverside County.	San Bernardino County.	Los Angeles County.	Total.
Lives lost	22	4	0	2	0	28
Agricultural lands	$1,500,000	$350,000	$350,000	$150,000	$500,000	$2,850,000
Municipal	72,850	32,000	50,000	.....	19,000	173,850
Water supply	1,225,500	57,000	67,450	.....	.....	1,349,950
Power plants	.....	.....	.....	94,565	1,600	96,165
Railroads [a]	.....	.....	.....	.....	.....	1,795,201
Highways and bridges	652,350	81,500	128,600	155,130	254,638	1,272,218
Telegraph and telephone lines [a]	.....	.....	.....	.....	.....	126,100
Miscellaneous	231,427	.....	9,000	200	.....	240,627

[a] The damage to railroads and telegraph and telephone lines was not reported in such shape that it could be segregated by counties.

LOSS OF LIFE.

Twenty-two persons were drowned in San Diego County. Most of them were living in Otay Valley and were swept away by the flood wave which was released from Lower Otay reservoir when the dam failed. A few lives were lost in Mission Valley, on San Luis Rey River. In Orange County four persons were drowned; two were in a cottage which floated down Santa Ana River, one was swept from the highway by the force of the water, and the other was in a wagon which was overturned. In San Bernardino County two men were drowned. No deaths were reported in Riverside and Los Angeles counties.

AGRICULTURAL LANDS.

San Diego County.—The valley lands along Tia Juana, Otay, Sweetwater, San Diego, San Dieguito, and San Luis Rey rivers were flooded. A large part of the bottom land was either cut up by new stream channels or covered with a large amount of sand, brush, and trees. A part of the land in each valley was quickly cleared, but there is a large area reclaimable only by large expenditures of time and money, and there are other large areas whose agricultural value was almost completely destroyed. An example is afforded by a tract of land in Otay Valley formerly used as a truck garden and valued at $1,000 per acre; after the flood 11 acres of this land were sold at a foreclosure sale for $100. The total damage to farm land was approximately $1,500,000. (See Pls. IV, V, VI.)

Orange County.—The total damage to agricultural lands in Orange County was approximately $350,000.

Riverside County.—The damage to lands in Riverside County is believed to have been at least $350,000.

San Bernardino County.—The damage to orange groves in San Bernardino County was considerable, and a number of the alfalfa ranches were practically ruined. The total damage was about $150,000.

Los Angeles County.—The principal injury to lands in Los Angeles County resulted from deposits of silt and the cutting of new stream channels. The damage was approximately $500,000.

MUNICIPAL PROPERTY.

San Diego.—The 300-foot concrete arch bridge across San Diego River at Old Town was wrecked (see Pl. VII, *A*) and five other bridges and numerous culverts were destroyed or seriously injured. The streets and roads in various parts of the city were washed or covered with débris. An approximate estimate of the total damage was $72,850.

San Bernardino.—The water main and several small pipe lines were washed out; two bridges were completely destroyed; and several sidewalks, curbs, and streets were damaged or destroyed. In addition several houses were washed away. The total damage was approximately $32,000.

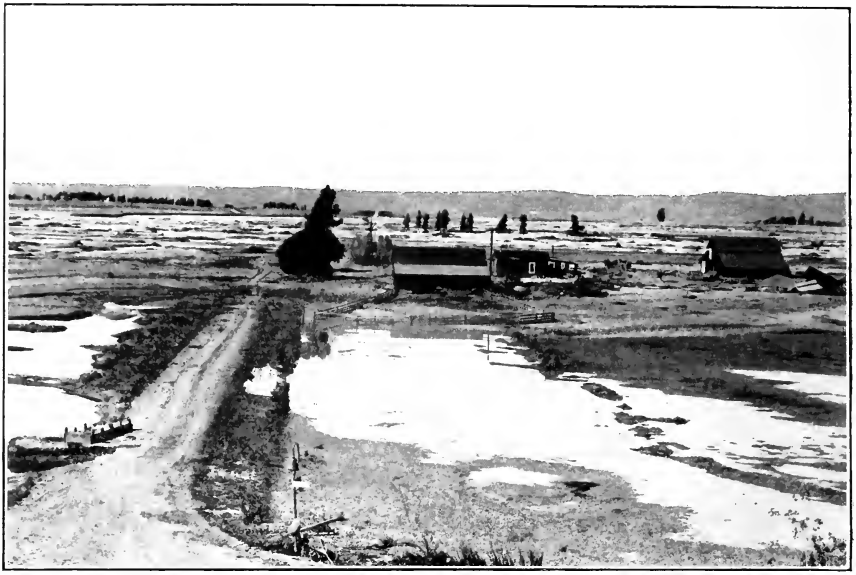
San Jacinto.—The damage to the water-supply systems, streets, and private property within the city limits was approximately $50,000.

Pomona.—The principal damage resulted from washes and fills in the streets. The estimated cost of repairs was $15,000.

Pasadena.—The damage to street improvements amounted to about $1,000, but otherwise there was no loss within the city.

A. VIEW UP MISSION VALLEY, SAN LUIS REY RIVER, IN 1915.

B. VIEW UP MISSION VALLEY, SAN LUIS REY RIVER, FEBRUARY 21, 1916.



A. VIEW ACROSS MISSION VALLEY, SAN LUIS REY RIVER, AT D. JONES'S RANCH, AFTER FLOOD OF JANUARY, 1916

B. VIEW UP SAN LUIS REY RIVER AT JUNCTION WITH MOOSA CANYON CREEK, AFTER FLOOD OF JANUARY, 1916.

Los Angeles.—A few unimportant wooden bridges were washed out and new channels formed. The damage was reparable at a cost of $3,000, which includes the removal of débris that collected at pile bents of several bridges.

WATER SUPPLY.

City of San Diego.—The failure of Lower Otay dam and the loss of the stored water was the most important damage (Pl. II). About 18 miles of Dulzura conduit was filled with débris and 2,800 feet of flume and concrete-lined section was destroyed. The road up Cottonwood Creek to Morena was seriously washed and blocked by slides. The washout of the pipe line across Sweetwater Valley prevented the delivery of water from this system. The loss of wells, pumps, and collecting pipe lines at the Mission Valley plant shut off the supply from this source. The total estimated damage was $897,500.

Sweetwater Water Co.—The north abutment of Sweetwater dam, consisting of a concrete-paved earth fill with reinforced concrete core wall, was overtopped to a depth of 3.64 feet and destroyed. The released water eroded the bedrock foundation at this end of the dam, leaving an opening about 50 feet deep and 100 feet long. Slight damages to the south abutment and spillway did not reduce the capacity of the reservoir. An earth dike, 650 feet long and 23 feet high, on the south side of the reservoir, about a mile above the dam, was overtopped and completely washed out. These breaks reduced the capacity of the reservoir from 35,000 acre-feet to 12,000 acre-feet. Temporary repairs increased the reservoir capacity to 25,000 acre-feet. In Sweetwater Valley 15,140 feet of pipe lines were washed out and other sections shifted or filled with sand. An approximate estimate of the cost of necessary repairs and enlarged spillway was $200,000. (See Pl. III, p. 25.)

Cuyamaca Water Co.—The principal damage was the loss of flume along upper San Diego River. The estimated cost of repairs to flume and pumping plants was $60,000.

South Coast Land Co.—The water supply for the town of Del Mar is obtained from wells on Santa Fe ranch in San Dieguito Valley, 6 miles above the mouth of the river. This pipe line was practically washed out. The new pipe line, completed about the middle of May, follows a new course along the foot hills.

The high water on January 17 did not damage the steam pumping plant in San Luis Rey Valley, but that of January 27 completely wrecked this plant and 2,000 feet of 16-inch pipe. Only one small section of the concrete building remained above the sand after the flood. The boilers were found 50 feet from their original position and covered with 30 feet of sand. The total damage to property of this company was about $60,000.

Escondido Mutual Water Co.—The principal damage was caused by slides which either filled or destroyed sections of the canal. About 8,000 yards of rock and earth were removed from the canal. Repairs were completed April 18 at a cost of about $8,000.

Temescal Water Co.—The main pipe lines and ditches were but slightly damaged. The loss on the tributary lines was much greater. In Mahew Canyon, 1,100 feet of 8-inch pipe was washed out. The dam at Lee Lake in Temescal Canyon failed, and a mile or more of 18-inch pipe line below the dam was washed out. The total damage was about $13,750.

Riverside Water Co.—The damage reported, including the rebuilding of the headworks, was approximately $10,000.

Lake Hemet Water Co.—The damage to headworks, canal, and pipe lines was about $43,700.

Anaheim Union Water Co.—The concrete head gate was undermined and washed out, several thousand feet of main canal were seriously injured, and considerable damage was done to the distribution system and roads. The total damage was about $57,000.[1]

POWER PLANTS.

Pacific Light & Power Corporation.—The Mentone plant on Santa Ana River was stopped on January 17 and started April 1. The masonry diversion dam, two masonry sand boxes, and 400 feet of concrete-lined canal were wrecked. A corner of the power plant was undermined, but the building was uninjured. The semicircular wood stave flume crossing the river from power house to North Fork ditch was completely carried away. The road up the canyon to the intake was practically all washed out. The transmission line was damaged but little, as it was on high ground. The total cost of repairs to this plant was $25,000.

The intake and 200 feet of pipe line were washed out at the Sierra plant on San Antonio Creek, as was also the road up San Antonio Canyon. The total cost of repairs was $1,600.

Southern California Edison Co.—The headworks and flume No. 8 at Santa Ana River plant No. 1 were destroyed, the buildings were seriously damaged, and a large amount of débris was deposited in the tailrace and on the floor of the power house. The siphon across Santa Ana River from the tailrace of plant No. 1 to intake of plant No. 2 collapsed. Plant No. 2 was not otherwise damaged, although a severe wash threatened to undermine the power house. The flume across the wash between Mill Creek power houses Nos. 2 and 3 was completely wrecked, and the pressure pipe line was washed out in several places. There were also minor damages to the headworks and various sections of flume on the canal lines. The intake for the

[1] From report to directors and stockholders on construction work for 1916.

A. WINSTON RANCH, MISSION VALLEY, SAN LUIS REY RIVER, FEBRUARY 21, 1916.

B. CANFIELD RANCH, NEAR BONSALL, SAN LUIS REY RIVER, FEBRUARY 21, 1916.

A. SAN DIEGO RIVER AT SAN DIEGO, AFTER FLOOD OF JANUARY, 1916.

Showing damage to county and Atchison, Topeka & Santa Fe Railway bridges.

B. SANTA MARGARITA RIVER NEAR MOUTH, AFTER FLOOD OF JANUARY, 1916.

Showing damage to State highway and Atchison, Topeka & Santa Fe Railway bridges.

Lytle Creek plant was seriously injured and the tailrace siphon was destroyed. Many of the wooden poles in the transmission line down Santa Ana Canyon were washed out. Several towers were also undermined along lower Santa Ana, San Gabriel, and Los Angeles rivers. The damage to the entire system was approximately $56,200.

Southern Sierras Power Co.—The damage to the system of the Southern Sierras Power Co. was principally confined to the transmission lines. Temporary repairs were completed in three days. The estimated damage was $13,365.

RAILROADS.

Atchison, Topeka & Santa Fe Railway Co.—The greatest damage to property belonging to the Santa Fe Railway Co. was on the line between Los Angeles and San Diego, where several miles of track, including many bridges and trestles, were entirely washed out. On the Fallbrook branch, which is 18 miles long, 4,500 feet of bridges was lost, 6½ miles of track disappeared, 4½ miles was washed off roadbed, and 4½ miles covered with sand. The damage in the other districts was less severe. Traffic was restored on the double track between San Bernardino and Barstow February 2; between San Bernardino and Redlands February 3; and on Temecula branch February 29. The line between Los Angeles and San Diego, including Escondido branch, was restored to traffic February 19. An approximate estimate of the total damage, made shortly after the flood, was $1,000,000. This estimate was based simply on replacing the track and roadbed to its original position and did not take into account any work that will be necessary to protect the track from future floods. (See Pls. VII and VIII, *A*.)

Southern Pacific Co.—The damage to the Southern Pacific system was estimated at $216,000. The first through eastbound passenger train after the flood left Los Angeles January 30, was held at Colton until 6.20 p. m. the following night and arrived at Yuma, Ariz., at 7.59 p. m. February 1. The first westbound passenger train after the flood reached Los Angeles at 1 a. m. February 1. The Tustin branch was opened to traffic February 7. The coast and valley lines north of Los Angeles were not seriously damaged.

Los Angeles & Salt Lake Railroad Co.—The excessive run-off began to weaken the structures on the Salt Lake line on January 17. In the Pasadena district traffic was delayed until January 21; in the first district—Los Angeles to Riverside—until January 22; and in the San Pedro district until January 28. Several bridges were injured and track was badly washed in many places. The total estimated cost of the repairs necessary to restore the lines in Los Angeles and Riverside counties was $50,000.

Pacific Electric Railway Co.—This company, in addition to its city lines, controls an extensive suburban system extending in all directions from Los Angeles. It serves parts of Los Angeles, San Bernardino, Riverside, and Orange counties. There were many interruptions to traffic during the flood period caused by washouts, flooded tracks, slides, and injury to bridges. Through traffic to Los Angeles over the Riverside-Rialto line, stopped by the loss of the Santa Ana bridge on January 17, was not completely resumed until March 3. Through service on the San Pedro-Los Angeles line was resumed January 31. The Newport line was not restored at Signal Hill until April 5 and was then operated with a single track until May 19. The total damage to property of this company was about $141,575.

San Diego & Southeastern Railway Co.—The total trackage of this company, including sidings and spurs, was 92.99 miles. The flood washed out 19.65 miles, or more than 21 per cent of the total track. The damage to the eastern division was caused principally by the floods on San Vicente Creek and San Diego River. All tracks in the Sweetwater Valley were washed out by the water released from Sweetwater reservoir after the break in the upper section of the dam. The failure of the Lower Otay dam resulted in the loss of all tracks in Otay Valley. The total estimated damage in the eastern and southern divisions was $318,626, including $30,000 for rolling stock.

Los Angeles & San Diego Beach Railway Co.—This road is within the city limits of San Diego. The damage included a trestle bridge 872 feet long and 2,700 yards of fill. The cost of the repair work was $14,000. Service was partly interrupted from January 11 to February 29, and wholly from January 29 to February 11.

San Diego & Arizona Railway Co.—The damage to this road resulted from the failure of the Lower Otay dam and the break in the Sweetwater dam. The cost of replacement and repairs to grade, track, culverts, and bridges was estimated at approximately $55,000.

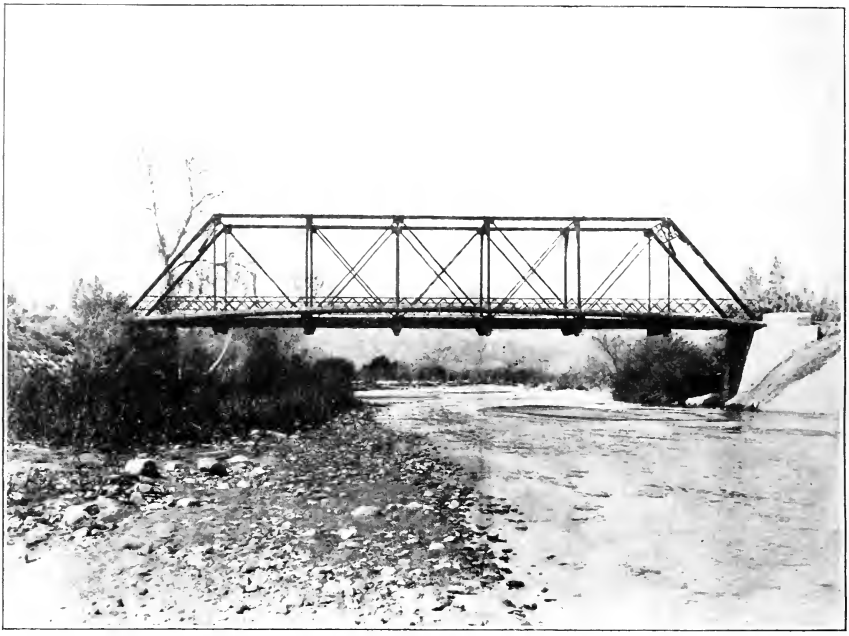
HIGHWAYS AND BRIDGES.

San Diego County.—Practically all important bridges in the county were washed out or became useless on account of changes in the channels of the streams. (See Pl. IX.) All roads were badly washed and some sections will require relocation when permanent repairs are made. Slides were numerous in the mountain districts, and all travel stopped until temporary repairs could be made. The estimated damage to county highways was $370,000 and to bridges, $225,000. The State highway to San Diego was closed until the middle of March. Several bridges or their approaches, including those across Santa Margarita Creek (Pl. VII, *B*), San Luis Rey River (700-foot reinforced-concrete arch bridge, Pl. VIII, *A*), and San Dieguito River,

A. VIEW UP SAN LUIS REY RIVER FROM MOUTH, AFTER FLOOD OF JANUARY, 1916.

Showing damage to Atchison, Topeka & Santa Fe Railway and State highway bridges.

B. DÉBRIS ON BEACH AT OCEANSIDE AND DELTA BUILT UP BY SAN LUIS REY RIVER, AFTER FLOOD OF JANUARY, 1916.



A. HIGHWAY BRIDGE ACROSS SAN LUIS REY RIVER AT PALA, BEFORE FLOOD OF JANUARY, 1916.

B. WRECK OF HIGHWAY BRIDGE ACROSS SAN LUIS REY RIVER AT PALA, AFTER FLOOD OF JANUARY, 1916.

were destroyed. Except for slight damage to shoulders and a few culverts, the concrete roadway was not injured. The damage to State highway, including repairs made during the storms, was about $57,350.

Orange County.—Almost the entire mileage of mountain roads will have to be rebuilt, as the grades were badly washed or buried by slides. The other graded and oiled roads were slightly damaged by deposits of débris and occasional washouts. The injury caused by undermining and shoulder cutting of paved highway was nominal. The loss of bridges was not considered, as they were old wooden structures which should have been replaced. The total damage was about $45,000. In addition, the State highway loss was approximately $36,500, including repairs made during the storms.

Riverside County.—The damage to 15 bridges, including 4 across Santa Ana River, was about $78,100. Several roads were badly washed out and the loss was approximately $32,000. The injury to State highway, including repairs made during the storms, was about $18,500.

San Bernardino County.—Nearly 40 bridges, including 3 across Santa Ana River, were washed out or damaged. The cost of replacement and repairs was about $67,524. The roads in every section of the county were seriously damaged. On Turner Avenue, Cucamonga, the entire street was washed out from 4 to 12 feet in depth for a distance of 4½ miles. Cajon and Mill Creek roads were badly washed and required extensive repairs. The damage to roads and culverts was about $80,656. The injury to State highways, including repairs made during the storms, was about $6,950.

Los Angeles County.—The estimated damage to roads and bridges was $228,388. In addition, the State highway loss, including repairs made during the storms, was about $26,250. A slide in section B, route 4, made it necessary to relocate the road.

TELEGRAPH AND TELEPHONE LINES.

Western Union Telegraph Co.—Practically all through lines were damaged by washouts at the principal stream crossings. Service was interrupted four days at the San Gabriel crossing, and the San Diego line closed for approximately a week. The total damage was about $23,500.

Postal Telegraph-Cable Co.—The main lines to San Francisco, San Diego, and the East were damaged and service interrupted. The Los Angeles-San Diego line was washed out at practically every river crossing and at numerous other points. Service between Los Angeles and San Diego was stopped for nearly a week, and the other lines were closed from one to three days. The total cost of repairs was about $5,000.

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Pacific Telephone & Telegraph Co.—The cost of reconstructing exchange lines, various sections of toll lines, and river crossings, either destroyed or rendered unsafe, was $97,600. Service, particularly over toll lines, was more or less interrupted for a period of approximately 606 hours.

MISCELLANEOUS DAMAGES.

San Diego Consolidated Gas & Electric Co.—The transmission lines and distribution system along San Diego River were washed out from El Monte to False Bay. There were also extensive washouts along Sweetwater River at Jamacho and from Sweetwater dam to San Diego Bay, on Otay River from Otay dam to San Diego Bay, and along Tia Juana River from Tia Juana to the Pacific Ocean. The principal damage was the loss of wood pole lines, copper wire, transformers, and miscellaneous electric-line material. The service in San Diego and immediate vicinity was not seriously interrupted. The lines to the more important towns were reestablished within two weeks, but some of the remote farming districts were without electric service for six weeks or more. The total damage to the gas and electric departments, corrected for value of salvaged material, was $70,527.

Western Salt Co.—The losses consisted of 170 acres of salt ground (which was covered with a deep deposit of silt), 2,500 tons of salt, a large quantity of brine in the ponds, and injury to machinery. The total damage was given as $85,500.

Fenton-Sumption-Barnes Co.—This company operates a gravel-washing plant in Otay Valley, about a mile from San Diego Bay. This plant was a complete loss, for after the flood there was not an indication on the surface to show its location. The value of this equipment was $35,000. In addition, the soil was entirely removed from 100 acres of bottom land which had been purchased for about $450 per acre. The business loss was complete from January 27 to May 1.

Indian reservations.—There was considerable damage to irrigation systems, buildings, and other improvements. In San Diego County the loss was approximately $38,000 and in Riverside County about $9,000.

Los Angeles Harbor.—About 2,030,000 yards of silt was deposited in the channels during the flood. These deposits did not reach the outer harbor or even the main turning basin and main entrance channel to an extent sufficient to interfere with commerce or require immediate dredging. At the extreme head of the harbor a channel reopened by a private corporation was filled with silt. There was also considerable silting in the East Basin channel.

Long Beach Harbor.—Navigation was greatly inconvenienced by very heavy silting in the different channels and basins. The total

deposit of silt was about 1,000,000 yards. The indirect damage to the various industries in the harbor district was probably much greater than the expenditures which will be necessary for dredging.

United States Geological Survey.—At the time of the flood the Survey was maintaining 23 river-measurement stations in the region covered by this report. All these stations were seriously damaged. The following equipment was lost: Six water-stage recorders, including wells and shelters; 17 staff gages; 10 cars and cables; and 8 concrete controls. In reequipping the stations it was found necessary, on account of great changes in the stream channels, to relocate two stations and abandon six. The total damage to equipment was about $2,600.

COMPARISON OF FLOOD OF 1916 WITH PREVIOUS FLOODS IN SOUTHERN CALIFORNIA.

BASIS OF COMPARISON.

To determine whether the flood of 1916 was more or less severe than previous floods in southern California, a search was made of the early records, and many old residents of the country were interviewed. The results of this work are summarized in the following pages. Of particular interest is the record of wet and dry years, compiled by Mr. A. Campbell, who has lived in San Diego County since 1869. Information as to conditions in most of the years prior to 1840 was taken from records of the Mission Fathers.

1770.....Drought.
1786.....Copious rainfall.
1787.....Rainfall insufficient; crops short.
1791.....Extremely dry; no rain for whole year.
1794.....Rainfall insufficient; crops short.
1795.....Very dry.
1811.....Flood year.
1815.....Flood year.
1819.....Short in rain and crops.
1825.....Great flood changed course of Santa Ana River.
1826, 1827, 1828.....Dry years (Gen. Vallejos.)
1832.....Short in rain and crops.
1840–41....Dryest year ever known.
1841–42....Wettest year ever known.
1842–43....Very open and dry.
1843–44....Very dry; no grain grown in Sacramento Valley
1845.....Drought.
1845–46....Wet in north; dry in southern California; cattle starved.
1846–47....Considerable rain; crops good.
1848–49....Most snowy winter known; rainfall moderate.
1849–50....One of the wettest and most floody winters.
1850–51....Open; rainfall moderate.
1853.....Big floods and snow.
1850–1856..Flood and good years.
1856–57....Dryest in 20 years.
1857–1862..Medium rainfalls.
1862–63....Dry years.
1863–1869..All good wet years.
1869.....A very exceptional year. In October the thermometer registered 110°, and a rainfall in December is estimated at 12 inches in 24 hours.
1869–70....Dry season.
1870–71....Dry season.
1872–74....Fairly wet seasons.
1875–76....Good rainfall.

1876–77....Dry season.
1877–1882..Good seasons.
1882–83....Dry years.
1883–84....Wettest winter known.
1885–1893..Series of good years.
1893–94....Short rainfall.
1895–6–7...Three good wet years.
1897–1900..Three dry years.
1901–1910..Fairly good wet years.
1910–1913..Dry years at end of season.
1912–13....Dry year.

The following additional information was obtained from "A history of California floods and droughts," by J. M. Guinn:

1822. A flood covered the lowlands and rose to a greater height than ever before known.
1851–52. A severe flood year in southern California. At Old Fort Miller on headwaters of San Joaquin River, Dr. W. T. Edgar, surgeon of the post, observed a rainfall of 46 inches during January and February, 1852.
1862. Santa Ana River at Anaheim ran 4 feet deep and spread in an unbroken sheet to Coyote Hills, 3 miles beyond. It rained 30 days in succession, beginning December 24, 1861.

FLOODS ON TIA JUANA RIVER.

Information concerning early floods on Tia Juana River was also furnished by Mr. Campbell, who considers the flood of 1884 the greatest in total run-off that has occurred during this time. The peak of that flood, however, was not so great as the peaks of the floods of 1891 and 1916, the only years in which, since 1869, water from Tia Juana River overflowed into the Otay drainage basin. In February, 1891, snow was above the fences at Mr. Campbell's ranch in Laguna Mountain divide, and one drift was 21 feet deep. This snow melted during a five days' rain. The lower Tia Juana Valley was flooded about as much in 1891, when the large hotel at Hot Springs, Mexico, was washed away, as in 1916. In comparing these floods the effect of storage at Morena reservoir in 1916 should be considered.

SWEETWATER RIVER.

Mr. C. H. Ellis, sr., who has lived near Descanso for 35 years, states that the floods of 1884 and 1916 were the largest on Sweetwater River within that period. At the site of the Geological Survey gaging station the water rose 3 to 4 feet higher in 1916 than in 1884. In 1916 the channel was wider and at least 2 feet deeper than in 1884. It is his opinion that the flood of 1916 was approximately double that of 1884.

The information presented in the following table was taken from a copy of the diary of the late William S. Gregg, Dehesa, Cal.:

Record of flood of 1884.

Date.	Rainfall.	Remarks.	Date.	Rainfall.	Remarks.
1884.	*Inches.*		1884.	*Inches.*	
Feb. 2–3	2	River came with flood Feb. 3. (Total rainfall, October to date, 10 inches.)	Mar. 27	½	
			28	1½	
			29	½	
5	1½		30–31	⅝	River rose a little.
6	2		Apr. 10	1½	
7	¼		12–13	⅜	
10–11	1	River rising.	16	(a)	
15	1¼	Cows over the river, can't get back.	28	¾	
			29	1	
16	1¼	River higher than for 20 years.	May 1	½	
			15	1½	
17–18	2¼	River higher. Over road to San Diego in two places.	18	.....	Cloudburst up by Harbinson's.
25	.....	Cattle, horses, etc., turned over river.	19	1	Last night.
			20	1¼	River high.
			June 1	.....	Total rainfall for season, 34¾ inches.
Mar. 3–6	2		1895.		
7	¼		Jan. 16	.....	Sweetwater River very high, higher than for 32 years. Great flood on. Farm covered with water from hill to hill Jan. 17.
10	1				
14–15	.....				
15	¾				
23	¼				
26	¼				

a Showers.

It is of interest to note that Mr. Gregg considered the flood of 1895 greater than that of 1884. The record [1] at Sweetwater reservoir shows that the total run-off of Sweetwater River for the year ending June 30, 1895, was 73,412 acre-feet; the record of J. F. Covert, chief engineer, Sweetwater Water Co., shows that the run-off at Sweetwater reservoir for January 16 to 31, 1916, was 111,000 acre-feet. (See pp. 48–49.) Mr. Covert gives the total run-off from October, 1915, to September, 1916, as 160,580 acre-feet.

SAN DIEGO RIVER.

The highest known discharge into Cuyamaca reservoir, stated in terms of maximum rate of inflow for 24 hours, is as follows:

	Second-feet.
1895, January 17	1,630
1906, March	1,120
1916, January 27	2,400

The following information was obtained in an interview with Mrs. Martha Swycaffer, who came to San Diego in 1854.

Mrs. Swycaffer states that the flood of 1862 was greater than any other within her time. The rain began in the fall of 1861 and the rainy season lasted until June, 1862. Beginning Christmas Day, a rain set in which lasted for at least six weeks, during which time there was not sunshine enough to dry a handkerchief. At about the end of this storm the rain set in more heavily, causing the big flood.

Before the peak the river occupied two channels, one on each side of the Swycaffers' home but a considerable distance from it. The

[1] McGlashan, H. D., and Dean, H. J., Water resources of California, part 3: U. S. Geol. Survey Water-Supply Paper 300, p. 493, 1913.

Swycaffer house was a two-story brick-veneered building. As the flood increased it was necessary to move into the upper story of the building, all the lower doors and windows being left open to ease the force of the flood. The Swycaffer house was the only one in the San Diego River bottom that stood, and all inhabitants in the vicinity sought refuge in the second story. The refugees were rescued from the second-story window in a surf boat manned by sailors, and Mrs. Swycaffer and three babies were then sheltered in an adobe house in Old Town. During the night a dike built for the protection of Old Town was overtopped, and her refuge was again flooded. The family was carried to the Old Palms and placed under the one which was out of water; the ground at the other was flooded.

The flood of 1862 was of long duration for a southern California stream, as it maintained approximately its peak height for 24 hours. Mrs. Swycaffer does not consider the flood of 1884 as large as that of 1916. In her opinion the flood of 1916 was next in magnitude to that of 1862.

Mrs. Swycaffer was familiar with what is now the Foster and Lakeside country. At Lakeside the high water reached to the old adobe ranch house, or an elevation of the present Lakeside store. At Foster the flood height reached nearly to the top of an immense oak, which was removed when the railway was built. This flood would have washed out all the present buildings in Foster. Previous to 1862 the present site of San Diego (New Town) was on rounded hills; the draws and gullies now existing were begun in 1862. When Mrs. Swycaffer first visited the Warner Hot Springs the springs broke out on a gradually sloping plain; the flood of 1862 made the topography as it is to-day.

Mrs. Swycaffer knew everyone in Old Town in 1862, and no flood within the memory of any or in the traditions of the place was comparable with it.

SAN LUIS REY RIVER.

In the early days houses and ranch buildings were built on high ground, and the bottom lands along the river channels were used only as pastures. As the number of settlers increased the agricultural lands became more valuble, and at the time of the floods of 1916 the bottom lands had reached a high state of cultivation and buildings were erected where they would be most convenient without any particular thought of the damage from excessive floods.

Mr. P. F. Hubbard, who has lived near San Luis Rey River since 1873, considers that the only flood in his time that is comparable with that of 1916 occurred in 1884. The flood of 1916 was 2 feet higher at

his well and the channel was wider than in 1884. The bottom lands in 1884 were covered with brush and trees and the channel did not cut much. As there were no cultivated fields or buildings in the path of the flood the damage was slight.

Mr. Edward Canterini, who has lived in San Luis Rey Valley since 1884, states that there was more rain in 1884 than in 1916 and the flood was of longer duration, but he does not consider that the maximum discharge was as great as in 1916. The river did not have a well-defined channel prior to 1891.

Immediately after the flood of January 27, 1916, Father Doyle, of the Pala Mission, San Diego County, talked with an old Indian who had lived along San Luis Rey River for many years. The Indian stated that this flood was greater than that of 1862. The old mission ditch at Pala, constructed more than 100 years ago, was washed out in a number of places by the flood of 1916, but previous floods had not injured it. Father Doyle considers the flood of 1916 the greatest which has occurred since the valley has been settled. The flood of 1862 he places second in size, and that of 1884, third.

Edward R. Bowen, in a paper on the San Luis Rey floods of January, 1916,[1] says:

> The entire San Luis Rey Valley was inundated, the stream extending from hill to hill—a distance of probably 1½ miles—and covering an area of over 1,000 acres. The drift along the county road on the south side of the valley indicated a 6-foot depth of water at that point. * * * It is probable that the enormous quantities of silt and débris carried by the stream in the first flood, together with that carried by the subsequent one, so built up and raised the old channel of the river that it was at a greater elevation than the adjacent valley lands. When the second flood came down this channel, its banks were overtopped and a new channel formed, cutting across the valley in a northeast to southwest direction, taking a long sweep to the westward at about the middle of the valley and returning to an old course near the narrows. * * * All farms in the valleys of the lower river were completely destroyed and three people were drowned. The entire valley is covered with deposit of sand and silt to an average depth of at least 3 feet, and in many places as much as 6 feet. Conditions along the upper river are not so bad. The valleys are more constricted and the stream better confined, although all crops along the bottom lands have been ruined. [See Pl. IV, *B*, p. 28.]

TEMECULA CREEK.

Mr. F. L. Fernold, of Temecula, Riverside County, reports that the flood of 1891 in Temecula Canyon rose to a height of about 2 feet on the trunk of a large oak tree on the bank at the ford. A neighbor, who was with him, said that this height was very close to the peak of the flood of 1884. This tree was washed out during the flood of January, 1916, after the water had risen about 12 feet on the trunk. The canyon at this point is in solid rock and conditions would be the same for all floods.

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[1] Eng. News, vol. 75, No. 8, p. 385, Feb. 24, 1916.

LOS ANGELES AND SAN GABRIEL RIVERS.[1]

There were heavy floods on Los Angeles and San Gabriel rivers in 1825, 1833, 1862, 1867, 1884 (2), 1886, 1889 (2), 1890, 1911, and 1914, and it is said that serious floods occurred also in 1842, 1852, and 1874. From the testimony in the case of Andres Daneri *v.* Southern California Railroad Co., superior court of Los Angeles County, in 1897, the largest floods occurred in 1825 and 1833 and the next largest flood was in 1862. It seems to be generally agreed that the greatest flood since 1862 occurred in 1889. The flood table prepared by the United States Weather Bureau, for the period 1878 to 1914, shows that 41 floods occurred in the vicinity of Los Angeles during this period.

The flood of 1909 in Los Angeles River was observed by H. Hawgood and William Mulholland (then superintendent of the Los Angeles City Water Co.). From the measured cross-section of the channel at the Southen Pacific Co's. crossing, on its main line east, and from the slope of the water surface, together with personal observations of the river at time of flood, Mr. Hawgood estimated that the maximum discharge was in excess of 35,000 second-feet. The details of the computation are not now available. The section observed by Mr. Mulholland was about 1,200 feet north of Buena Vista bridge. Here the surface velocity, as observed from débris floating down the stream, was 14 to 16 miles per hour. The depth of water was given as 9 feet and the width as 300 feet. The discharge, as computed from these data by Mr. Hawgood, was approximately 45,000 second-feet.

FLOOD RUN-OFF IN JANUARY, 1916.

COLLECTION OF RECORDS.

At the beginning of the first storm on January 17, Mr. Ebert reached San Gabriel River near Azusa, and on January 17 and 18 he made float measurements just below the gage; the cable was not accessible, as the highway was washed out above the mouth of the canyon. January 20 he attempted to reach Santa Ana River near Mentone, but found the highway impassable east of Highland. The highway west of Azusa was also closed on account of the damage to the San Gabriel bridge. The Pacific Electric Railway was opened from Azusa to Los Angeles January 21.

Mr. Ebert left Los Angeles for San Diego by the inland route January 24 and reached Escondido the night of January 26. The heavy rainfall during that night destroyed the highways in all directions, and he was detained there by the condition of the roads

[1] Abstracted from reports of the Board of Engineers Flood Control to the Board of Supervisors, Los Angeles County, Cal., submitted July 27, 1915, pp. 144–146 and 172–174.

until February 5, when his automobile was drawn across San Dieguito River at Bernardo by a four-horse team, and he reached Lakeside that night by way of Poway grade, Miramar ranch, and Pacific Beach. A measurement could not be made on San Diego River at Lakeside, as the cable had been washed out and the river was flowing in a wide channel to the right of the highway bridge. The following day he visited Sweetwater River near Descanso, but on account of the damage to highways he was unable to reach any other stations in this territory or those on Santa Ysabel Creek and upper San Luis Rey River. He made the return trip from San Diego by boat February 9.

In March, 1916, Mr. McGlashan and Mr. Ebert made an extensive trip through the region covered by this report to obtain available flood data and to collect records obtained by private parties. They visited the river-measurement stations that were accessible at this time, and also a number of streams on which no stations were being maintained. The flood marks were still very distinct, so that it was possible to make numerous measurements of slope and of cross sections of river channels at maximum stage, and to obtain other data necessary for the computation of flood flow. The results were computed by Kutter's formula, after carefully selecting values of n. The base data, as well as the computed records, are here published, to enable any engineer engaged in a detailed study of the run-off to make independent computations of the flow.

TIA JUANA RIVER BASIN.

GENERAL FEATURES.

Tia Juana River discharges into the Pacific Ocean below San Diego Bay near the Mexican boundary. Its principal tributary, Cottonwood Creek, rises in the Laguna Mountains of the Coast Range and flows southwestward about 32 miles to its junction with Tia Juana River at the Mexican boundary, about 22 miles east of the coast line. The total drainage area of Cottonwood Creek above its junction with Tia Juana River is approximately 340 square miles. It lies south of the Sweetwater and Otay River basins, and is the most southerly stream in San Diego County. Pine Valley Creek, which joins it 20 miles below its source, is its only important tributary.

The topography of the basin of Cottonwood Creek is rough throughout, although some valley areas are found above the 3,000-foot contour. Below this elevation the stream flows through a deep, narrow canyon, broken only by a short stretch of open country with comparatively light grade at the junction of Pine Valley Creek. Altitudes range from 600 feet above sea level, where the creek joins Tia Juana River, to 5,000 feet on the Laguna Mountains.

The Cottonwood basin is poorly forested. The timber consists of scattered oaks, cottonwoods, and alders, which are restricted almost entirely to the small valleys along the stream and to the higher elevations. The mountain slopes are fairly well covered with brush.

The mean annual rainfall ranges fron 8 to 10 inches along the foothills and from 20 to 30 inches in the mountains.

COTTONWOOD CREEK AT MORENA RESERVOIR, CAL.[1]

LOCATION.—In the SW. ¼ sec. 14, T. 17 S., R. 4 E., three-fourths mile north of Morena Butte, 1¾ miles above mouth of Hauser Creek, and 8½ miles upstream from Barrett dam, San Diego County.

DRAINAGE AREA.—119.5 square miles (reported by George Cromwell).

ELEVATION.—About 3,000 feet above sea level.

DISCHARGE.—Computed from gage-height record showing storage in reservoir, corrected for waste through spillways and outlet tower.

SPILLWAY.—Consists of 12 openings, each 8½ feet in length, controlled by independent radial gates. All gates were open until 7 a. m., January 29, when 11 were closed. At 11 a. m., January 29, 6 gates were opened and at 5 p. m. the remainder were opened. January 30 at 7 a. m., all gates were closed. Two gates were opened at 7 a. m., January 31 and the remainder at 6 p. m.

Average depth of water in spillway was as follows: January 28, 4 feet; January 29, 3.25 feet; January 31, 3 feet. Considerable drift collected at the spillway which interfered with the operation of the gates.

Maximum capacity of spillway, 5,380 second-feet and of outlet tower, 483 second-feet.

OUTLET TOWER.—There are 5 valves in the tower. Number 4, at 99.5 feet, was opened January 28 at 1.30 a. m. and closed January 29 at 6.30 a. m. No other valves were opened during the month.

MAXIMUM DISCHARGE IN JANUARY, 1916.—January 27, 7 a. m. to 4 p. m., 8,785 second-feet; 4 p. m. to 6 p. m., 15,356 second-feet; 6 p. m. to 12 p. m., 13,344 second-feet. January 28, 12 a. m. to 7 a. m., 3,157 second-feet.

The following table contains data furnished by George Cromwell, city engineer, San Diego, Cal.:

[1] O'Shaughnessy, M. M., Construction of the Morena rock-fill dam, San Diego County, Cal.: Am. Soc. Civil Eng. Trans., vol. 75, p. 27, 1913.

Gage height and discharge of Cottonwood Creek at Morena reservoir, Cal., for January, 1916.

Day (7 a. m.)	Gage height (feet).	Storage (million gallons).	Waste.		Run-off from drainage basin.		
			Million gallons.	Acre-feet.	Million gallons.	Acre-feet.	Second-feet.
Jan. 1	118.68	5,189			4	12.3	6.2
2	118.70	5,193			2	6.1	3.1
3	118.71	5,195			4	12.3	6.2
4	118.73	5,199			9	27.6	13.9
5	118.77	5,208			4	12.3	6.2
6	118.79	5,212			5	15.4	7.7
7	118.82	5,217			4	12.3	6.2
8	118.84	5,221			10	30.7	15.5
9	118.89	5,231			6	18.4	9.3
10	118.92	5,237			38	116.7	58.8
11	119.11	5,275			12	36.0	18.6
12	119.17	5,287			4	12.3	6.2
13	119.19	5,291			4	12.3	6.2
14	119.21	5,295			103	416.8	159.4
15	119.72	5,398			77	236.4	119.2
16	120.01	5,475			910	2,793.7	1,408.6
17	124.19	6,385			1,469	4,509.8	2,273.0
18	130.00	7,854			1,248	3,831.4	1,931.0
19	134.20	9,102			318	976.3	492.3
20	135.21	9,420			214	656.9	331.7
21	135.80	9,634			120	368.4	185.7
22	136.17	9,754			109	334.6	168.7
23	136.51	9,863			93	285.5	143.9
24	136.80	9,956			115	353.1	178.2
25	137.15	10,071			169	518.8	261.6
26	137.64	10,240			271	831.9	419.5
27	138.40	10,511	768	2,357.6	5,707	17,520.5	8,834.3
28	150.50	15,450	1,728	5,304.9	1,278	3,923.5	1,978.3
29	149.50	15,000	900	2,763.0	675	2,072.3	1,044.8
30	149.00	14,775			225	690.7	348.2
31	149.50	15,000	659		211	647.7	326.6
Feb. 1	148.50	14,552					

Total run-off for month	acre-feet	41,200
	depth in inches on drainage area	6.43

OTAY RIVER BASIN.

GENERAL FEATURES.

Otay River drains the region between Sweetwater basin on the north and Tia Juana on the east and south. Above Lower Otay dam it has a drainage area of 98.6 square miles. The general course of the stream is southwest, and it enters San Diego Bay at the extreme southern end, about 4 miles north of the International boundary.

Above Lower Otay reservoir the stream is known as Jamul Creek, to which Dulzura Creek is tributary. The natural run-off from this area is increased by the water diverted from Cottonwood Creek through Dulzura conduit, into Dulzura Creek. The drainage area of Jamul Creek is mountainous and the slopes are very steep. The highest point is Lyons Peak; elevation, 3,755 feet. The forest cover is mainly brush, except in the vicinity of the stream channels.

The mean annual precipitation ranges approximately from 8 to 20 inches.

OTAY RIVER AT LOWER OTAY RESERVOIR,[1] NEAR OTAY, CAL.

LOCATION.—The dam was in the extreme northwest corner of sec. 18, T. 18 S., R. 1 E., at the head of the canyon above Otay Valley, about 16 miles southeast of San Diego and 8 miles east of Otay, San Diego County.

DRAINAGE AREA.—98.6 square miles (measured on topographic map; includes 12.7 square miles, tributary to Upper Otay reservoir)

ELEVATION.—Top of dam was about 480 feet above sea level.

GAGE.—Vertical staff fastened to outlet tower (Pl. II, *A*). Zero of gage, 346.65 feet above sea level, U. S. Geological Survey datum. The gage-height record for January 22–27, 1916, given in the storage table for the reservoir, was obtained from employees at the reservoir a short time after the dam failed. The record January 15–21 was published in the Engineering Record for February 12, 1916.

SPILLWAY.—Built of concrete at left of dam; width on bottom, 37.9 feet; width at top, 41.5 feet; depth, 8 feet; uniform slope, 0.00365. Floor of spillway is 123.3 feet above zero of gage. It is stated that the spillway has the same dimensions throughout its length, and hence did not admit sufficient water to fill the channel for its entire length. The discharge of the spillway at the time the dam failed was 4,700 second-feet according to George Cromwell, city engineer.[2] John L. Bacon, former assistant city manager, estimated the maximum discharge of the spillway as 2,000,000,000 gallons daily, or 3,100 second-feet.[3]

OUTLET TUNNEL.—There was no provision for blow-off from the reservoir except through the outlet tunnel, which connected with the pipe line to San Diego. At the lower end of the tunnel there was a Y connection with a 36-inch blow-off valve, which was opened at noon January 27, 1916. The maximum capacity through this blow-off was 330 second-feet, according to George Cromwell, city engineer.[4]

MAXIMUM DISCHARGE IN JANUARY, 1916.—The maximum gage height in the reservoir was reported as 134.0 feet at 5.05 p. m., January 27, at which time the dam failed. From the table showing storage in reservoir, the rate of inflow from 4.25 p. m. to 5.05 p. m. was 32,700 second-feet. If the maximum discharge of the spillway as given by the city engineer is added, the total was 37,400 second-feet, or 379 second-feet per square mile of drainage area.

Data concerning cross sections and slope were obtained on Jamul Creek (see p. 45) just above effect of backwater from the reservoir. The maximum discharge at this point was computed as 18,100 second-feet, or 259 second-feet per square mile of drainage area. If this same rate of run-off is assumed for the 12.7 square miles of drainage area above Upper Otay dam, the maximum flow over the dam and through spillway did not exceed 3,300 second-feet.

George Cromwell, city engineer,[4] stated that the run-off into the Lower Otay reservoir was 23,500 second-feet for a period of one hour prior to the failure of the dam. This rate would allow a run-off from the drainage area directly tributary to the reservoir, exclusive of Upper Otay reservoir and Jamul Creek, of 2,100 second-feet, or 130 second-feet per square mile, provided the crest discharges all reached Lower Otay reservoir at the same time.

The maximum discharge computed from the reservoir record exceeds that published by Mr. Campbell by nearly 60 per cent. The run-off per square mile computed from the reservoir record is more than 50 per cent greater than that reported for Sweetwater River at Sweetwater dam. See table of crest discharge (p. 23) for maximum discharge for other streams in this region. The mean rainfall, computed for drainage area above Lower Otay dam, was 19.2 inches; that for Sweetwater River above Sweetwater dam was 21.8 inches. (See table, p. 11.)

[1] See pp. 25–26 for description of failure of dam on Jan. 27, 1916.
[2] Eng. News, Apr. 13, 1916, p. 717.
[3] Idem, Feb. 3, 1916, pp. 236–239.
[4] Idem, Apr. 13, 1916, p. 718.

AUTHORITY.—Data for this station were obtained in the field, from the publications cited, and from other reliable sources. Data collected by the city of San Diego were withheld because of pending litigation.

Storage in Lower Otay reservoir for January, 1916.

Date.	Time.	Gage height (feet).	Available storage.		Increase in storage.[a]	
			Million gallons.	Acre-feet.	Acre-feet.	Second-feet.
Jan. 15		84.0	3,610	11,100		
17		101.0	6,230	19,100	8,000	2,020
18		111.0	8,350	25,600	6,500	3,280
19		118.7	10,200	31,300	5,700	2,870
21		122.8	11,340	34,800	3,500	882
22	7 a. m.	123.3	11,490	35,300	500	252
23	7 a. m.	123.6	11,580	35,600	300	151
24	7 a. m.	123.8	11,640	35,700	100	50
25	7 a. m.	123.95	11,680	35,900	200	101
26	7 a. m.	124.0	11,700	35,900	0	0
27	7 a. m.	124.9	11,970	36,700	800	403
	Noon.	127.9	12,950	39,800	3,100	7,500
	3 p. m.	130.0	13,650	41,900	2,100	8,470
	4 p. m.	131.3	14,080	43,200	1,300	15,700
	4.25 p. m.	132.3	14,440	44,300	1,100	31,900
	5.05 p. m.	134.0	15,030	46,100	1,800	32,700

[a] Discharge through spillway not included.

NOTE.—The available storage in million gallons, given in the above table, was taken from a capacity curve compiled in the office of the city engineer, San Diego. Gage-height record, Jan. 15–21, was published in Engineering Record for Feb. 12, 1916; Jan. 22–27 was obtained from employees of the city of San Diego at the dam a short time after the failure.

JAMUL CREEK NEAR OTAY, CAL.

LOCATION.—In sec. 4, T. 18 S., R. 1 E., about 500 feet above highway crossing above Harvey ranch and well above backwater from Lower Otay reservoir at high-water elevation, and about 11 miles east of Otay, San Diego County.

DRAINAGE AREA.—69.8 square miles (measured on topographic map).

ELEVATION.—About 500 feet above sea level.

CHANNEL.—Composed of sand, gravel, and boulders; practically straight for the section covered by slope data, but curves to the left just below point where lower cross section was taken. Banks high and practically clean after flood (Pl. X, *B*). Channel apparently fairly permanent.

MAXIMUM DISCHARGE IN JANUARY, 1916.—Measurements of slope and of two cross sections were made March 17, 1916. Slope of water surface that day was determined for a distance of 935 feet. The determination of high-water slope checked fairly well with that of the slope of the water surface March 17, but could not be ascertained so accurately on account of the roughness of the banks. The maximum discharge has been computed as follows: Mean width, 158 feet; mean area, 1,360 square feet; mean wet perimeter, 164 feet; mean hydraulic radius, 8.3; present slope of water surface, 0.0071 (for 935 feet) March 17, 1916. If the value of n in Kutter's formula is assumed as 0.04, the discharge is 18,100 second-feet, or 259 second-feet per square mile of drainage area.

SWEETWATER RIVER BASIN.

GENERAL FEATURES.

Sweetwater River rises in the south and east slope of the Cuyamaca Mountains of the Coast Range, flows nearly due south for 15 miles, then turns to the west and southwest and discharges into San Diego Bay south of National City. Its length is 45 miles, and its area

comprises approximately 215 square miles, the greater part of which is in mountainous country. The basin is extremely narrow. It lies directly south of San Diego River and north of the Otay River and Cottonwood Creek basins.

The topography is not so rough as that of San Diego River basin, although the mountains and foothills extend within 3 or 4 miles of the shore line of San Diego Bay, and the valley and mesa lands are not so extensive as along San Diego River. The basin is poorly forested. The timber is confined almost to the immediate valleys of the streams and to the higher mountain areas. The mountain slopes have a fairly good covering of brush, but the lower foothills are almost bare, supporting only a sparse growth of low brush.

The mean annual rainfall varies from 10 to 15 inches along the foothill belt and from 20 to 45 inches in the mountains.

A considerable area lying between San Diego Bay and the foothills south from National City to the Mexican boundary is under a high state of cultivation. The greater part of this land is irrigated by water taken from Sweetwater River.

SWEETWATER RIVER NEAR DESCANSO, CAL.

LOCATION.—In the SE. ¼ sec. 25, T. 15 S., R. 3 E., at Ellis ranch, 2 miles below mouth of Guatay Creek and about 1½ miles below Descanso, San Diego County.

DRAINAGE AREA.—43.7 miles (measured on topographic and military-survey maps).

ELEVATION.—About 3,300 feet above sea level.

RECORDS AVAILABLE.—November 21, 1905, to January, 1916.

GAGE.—Staff in three sections on left bank at concrete control, a short distance below intake of Ellis ditch; destroyed by the flood of January, 1916. Installed at same datum and practically same location as previous gage.

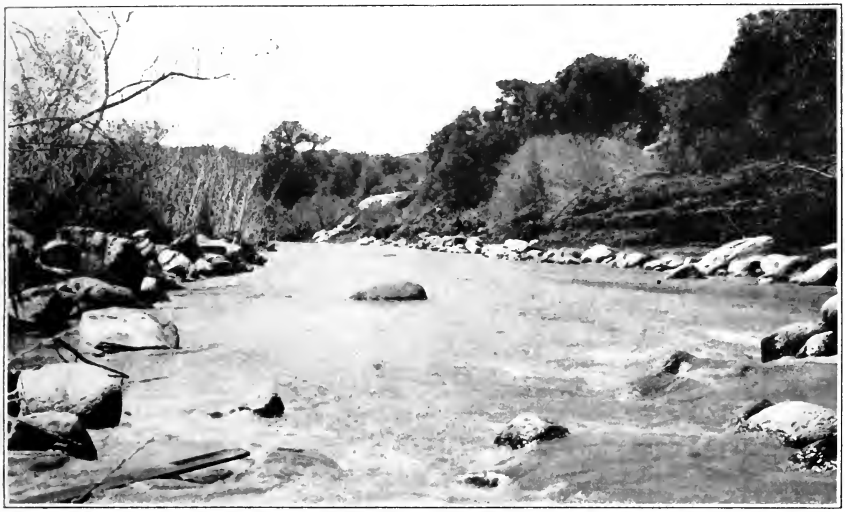
DISCHARGE MEASUREMENTS.—Made from cable at gage or by wading. No measurements were made during the flood of January, 1916, as the highways were impassable.

CHANNEL AND CONTROL.—Channel composed of sand, fine gravel, and boulders; shifting. Banks are high and not subject to overflow. A concrete control constructed October 11, 1914, across the channel opposite original gage was practically destroyed by the flood of January, 1916.

EXTREMES OF DISCHARGE.—1905–1915: Maximum stage recorded, 9.25 feet at 5 p. m. March 24, 1906 (approximate discharge, computed from extension of rating curve, 3,000 second-feet); channel dry during a portion of the years 1910, 1911, and 1913.

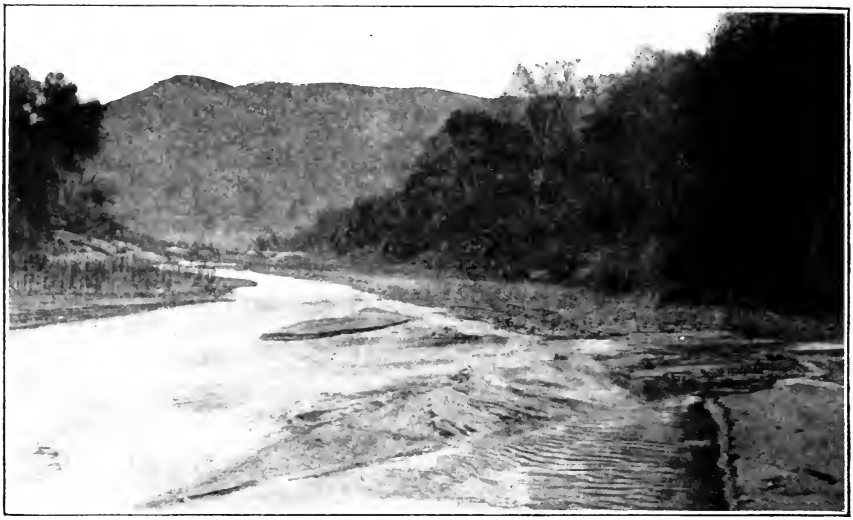
MAXIMUM DISCHARGE IN JANUARY, 1916.—No gage-height record after January 23, when gage was washed out. Measurements of slope and two cross sections were made March 13, 1916, in the vicinity of the gaging station. The channel (Pl. X, *A*), is practically straight for the section covered by slope data. Banks high and covered with brush and small trees.

The maximum discharge has been computed from the mean of the two cross-sections, as follows: Mean area, 987 square feet; mean hydraulic radius, 6.0; slope of water surface, 0.0078 (for 875 feet) March 13. If the value of n in Kutter's formula is assumed as 0.045, the discharge is 9,870 second-feet, or 226 second-feet per square mile of drainage area.



A. VIEW DOWNSTREAM ON SWEETWATER RIVER NEAR DESCANSO, AFTER FLOOD OF JANUARY, 1916.

B. VIEW UPSTREAM ON JAMUL CREEK NEAR OTAY, AFTER FLOOD OF JANUARY, 1916.



A. VIEW UPSTREAM SHOWING CAPITAN GRANDE DAM SITE ON SAN DIEGO RIVER, AFTER FLOOD OF JANUARY, 1916.

B. VIEW UPSTREAM ON SAN VICENTE CREEK AT FOSTER, AFTER FLOOD OF JANUARY, 1916.

ACCURACY.—Determinations of discharge January 16 to 22, roughly approximate as they are computed from an extension of the rating curve for 1914-15, which is unsupported by high-water measurements. It is assumed that the concrete control was not disturbed until the second rise, which occurred January 27.

Gage height, in feet, and discharge, in second-feet, of Sweetwater River near Descanso, Cal., for January, 1916.

Date.	9 a. m.		5 p. m.	
	Gage height.	Discharge.	Gage height.	Discharge.
Jan. 14	1.38	21	1.38	21
15	2.20	137	2.20	137
16	2.30	159	4.40	1,060
17	6.00	2,500	6.00	2 500
18	6.00	2 500	4.70	1 290
19	4.00	822	3.80	716
20	3.70	666	3.50	570
21	3.50	570	3.50	570
22	3.50	570	3.80	716

NOTE.—For maximum discharge during January see description of station. No record Jan. 23 to 31, as gage was washed out.

SWEETWATER RIVER NEAR DEHESA, CAL.

LOCATION.—In the NW. ¼ NW. ¼ sec. 20, T. 16 S., R. 2 E., at Sloane ranch, 1,000 feet below mouth of Lawson Creek, about 3 miles southeast of Dehesa, San Diego County.

DRAINAGE AREA.—112 square miles (measured on topographic and military-survey maps).

ELEVATION.—About 900 feet above sea level.

RECORDS AVAILABLE.—December 4, 1913, to January, 1916.

GAGE.—Bristol water-stage recorder on left bank 5 feet above control; destroyed by flood of January, 1916. No gage-height record available for that month.

DISCHARGE MEASUREMENTS.—Made from cable 200 feet below concrete control or by wading; equipment destroyed by flood, January, 1916; no discharge measurements were made during that month.

CHANNEL AND CONTROL.—Bed composed of shifting sand overlying solid rock. The concrete control, which extended to bed rock, was destroyed by the flood of January, 1916. Banks are high and not subject to overflow.

EXTREMES OF DISCHARGE.—1913-1915: Maximum stage recorded, 5.8 feet February 11, 1915 (approximate discharge computed from extension of rating curve, 1,750 second-feet); channel practically dry August 12, 1915, to end of year.

MAXIMUM DISCHARGE IN JANUARY, 1916.—Mr. J. F. Covert, chief engineer, Sweetwater Water Co., measured cross sections and obtained slope data at this station. Determinations of maximum discharge for the flood of January, 1916, based on these data, were furnished by F. C. Finkle, consulting engineer, as follows: Mean area, 1,639 square feet; mean wet perimeter, 184 feet; mean hydraulic radius, 8.9; slope, .0047; assumed value of n in Kutter's formula, .03; coefficient c., 72.5; mean velocity, 14.82 feet per second; discharge, 24,295 second-feet or 217 second-feet per square mile of drainage area.

SWEETWATER RIVER AT RUDOLPH RANCH, NEAR DEHESA, CAL.

From measurements of cross sections and slope at the highway crossing near south line of sec. 14, T. 16 S., R. 1 E., San Diego County, made by J. F. Covert, chief engineer, Sweetwater Water Co., the

maximum discharge for the flood of January, 1916, was computed and furnished by F. C. Finkle, consulting engineer, as follows: Mean area, 2,382 square feet; mean wet perimeter, 485 feet; mean hydraulic radius, 4.9; slope, 0.0045; assumed value of n in Kutter's formula, 0.025; coefficient c, 77.9; mean velocity, 11.56 feet per second; discharge, 27,530 second-feet or 204 second-feet per square mile (drainage area given as 135 square miles).

SWEETWATER RIVER NEAR JAMACHO, CAL.

Measurements of cross sections and slope made by J. F. Covert, chief engineer, Sweetwater Water Co., at Jamacho Canyon, San Diego County, were used by F. C. Finkle, consulting engineer, to compute the maximum discharge for the flood of January, 1916, with the following results:

Mean area, 3,006 square feet; mean wet perimeter, 410 feet; mean hydraulic radius, 7.3; slope, 0.0057; assumed value of n in Kutter's formula, 0.03; coefficient c, 70.2; mean velocity, 14.3 feet per second; discharge, 43,002 second-feet or 250 second-feet per square mile (drainage area given as 172 square miles).

SWEETWATER RIVER AT SWEETWATER DAM, CAL.

The following table was prepared by J. F. Covert, chief engineer, Sweetwater Water Co., for court use. It is known as Exhibit L in the Neuman case and Exhibit J in the Sutliff case. Sweetwater reservoir is on Sweetwater River about 6½ miles northeast of National City, San Diego County. The drainage area tributary to the reservoir is 181 square miles (measured on topographic and military survey maps).

Discharge, in second-feet, of Sweetwater River at Sweetwater dam, Cal., for Jan. 16 to 31, 1916.

Date.	Time.	Accumulative run-off.	Waste.				Total discharge.	Mean daily discharge.
			Through blow-off.	Spillway.	Over parapet.	Through breaks.		
Jan. 16	8 a. m. to 5 p. m.	809					809	1,530
16-17	5 p. m. to 3 a. m.	4,215					4,215	
17	3 a. m. to 8 a. m.	6,050					6,050	5,870
17	8 a. m. to 11 a. m.	4,185	232				4,417	
17	11 a. m. to 3.15 p. m.	4,185	232				4,417	
17	3.15 p. m. to 5.15 p. m.	5,950	232				6,182	
17	5.15 p. m. to 9 p. m.	9,090	232				9,322	
17	9 p. m to 11 p. m.	5,580	232				5,812	
17-18	11 p. m. to 3 a. m.	6,130	232	560			6,922	
18	3 a. m to 5 a. m.	6,130	232	1,629			7,991	5,900
18	5 a. m to 8 a. m.	1,740	232	2,358.2			4,330	
18	8 a. m. to 12 m.	2,500	372	2,775.7			5,648	
18	12 m. to 5 p. m.	2,500	719	3,220			6,439	
18	5 p. m. to 8.30 p. m.	1,488	720	3,658			5,866	
18	8.30 p. m. to 10.30 p. m	802	721	3,932			5,455	
18-19	10.30 p. m to 4.30 a. m.	− 689	719	3,737.6			3,768	
19	4.30 a. m. to 5 p. m.	−1,248	716	3,297.7			2,766	2,770
19-20	5 p. m. to 6 a. m.	−1,186	714	2,606.7			2,135	
20	6 a. m to 5 p. m.	−1,023	711	1,586.5			1,274	1,400
20-21	5 p. m to 7 a. m.	− 495	709	883			1,097	
21	7 a. m. to 5 p. m.	− 600	706	518.5			625	707
21-22	5 p. m. to 5 a. m.	− 87	181	340.5			434	
22	5 a. m. to 8 a. m.		181	157.5			339	356
22	8 a. m. to 5 p. m.	339					339	
22-23	5 p. m. to 8 a. m.	331					331	
23	8 a. m. to 5 p. m.	318					318	295
23-24	5 p. m. to 7 a. m.	225					225	
24	7 a. m to 5 p. m.	215.5		23.8			239	226
24-25	5 p. m. to 7 a. m.	126.5		83.1			210	277
25-26	7 a. m. to 7 a. m.	112.8		190.6			304	367
26-27	7 a. m. to 4.30 a. m.	77.2		316			393	
27	4.30 a. m. to 7 a. m.	1,850		545			2,395	15,000
27	7 a. m. to 9 a. m.	1,928	326	895			3,149	
27	9 a. m. to 11 a. m.	1,948	347	1,314			3,609	
27	11 a. m. to 11.45 a. m.	7,790	368	1,803			9,961	
27	11.45 a. m. to 1 p. m.	13,060	368	2,826			16,254	
27	1 p. m to 2.20 p. m.	17,180	368	4,063			21,611	
27	2.20 p. m. to 4.08 p. m.	24,200	408	4,953.4	3,860		33,421	
27	4.08 p. m. to 4.30 p. m.	16,280	448.5	5,460.4	8,530	8,181	38,900	
27	4.30 p. m. to 5.30 p. m.	−2,550	449	5,503	9,090	33,008	45,500	
27	5.30 p. m. to 6.30 p. m.	−43,300	444	5,049	4,420	70,487	37,100	
27	6.30 p. m. to 9 p. m.	−31,050	434	2,314		59,902	31,600	
27-28	9 p. m. to 8 a. m.	−9,870	419.8			25,050	15,600	
28	8 a. m. to 5 p. m.	−5,970	400			14,570	9,000	9,970
29		−1,288	429			5,649	4,790	4,790
30		− 481	469			4,022	4,000	4,000
31		− 369.5	469			2,640	2,740	2,740

Total run-off for period { acre-feet 111,000
depth in inches on drainage area 11.55

NOTE.—Mean daily discharge, total discharge in acre-feet, and run-off in depth in inches computed by Engineers of United States Geological Survey.

SAN DIEGO RIVER BASIN.

GENERAL FEATURES.

San Diego River rises in the Cuyamaca Mountains, on the western slope of the Coast Range, flows southwestward, and discharges into Pacific Ocean through False Bay at the northern boundary of San Diego City. Its length is about 50 miles, half of which lies in the mountains above the town of Lakeside. The San Diego basin has an area of 434 square miles and lies directly south of the San Dieguito basin and north of the Sweetwater River basin.

The San Diego has several small tributaries, the most important being Coleman, Cedar, Boulder, South Fork, and Chocolate creeks, all of which enter from the east and south above Lakeside. San Vicente Creek, the only important tributary from the north, enters the river at Lakeside.

The upper part of the basin above Lakeside is extremely rough and rugged, but below Lakeside numerous valleys and high mesa lands extend to the coast. Elevations throughout the basin range from 50 to 600 feet in the foothills and from 600 to 6,000 feet in the mountains. Cuyamaca Peak, the highest point in the basin, has an elevation of 6,028 feet. The formation is the loose granite that is typical of all river basins in San Diego County.

The San Diego basin is poorly forested. The timber is confined almost entirely to the valley along the streams and to the higher mountain areas. The mountain slopes are fairly well covered with brush, but the lower foothills are almost entirely bare, supporting only a scattered growth of low brush.

The mean annual rainfall ranges from 10 to 15 inches along the foothill belt, and from 20 to 45 inches in the mountains.

Irrigation is carried on extensively in the valleys and on the mesa lands between Lakeside and San Diego, and additional areas might be irrigated if an adequate supply of water could be assured. Two storage reservoirs have been constructed: The Cuyamaca reservoir is on Boulder Creek, at an elevation of 4,600 feet above sea level, and has a capacity of 11,400 acre-feet with a 35-foot earthen dam. La Mesa reservoir is in the foothills about 2 miles northwest of the town of La Mesa, at an elevation of 435 feet. The dam is of earth and rock, is 66 feet high, and has a storage capacity of about 1,500 acre-feet. La Mesa reservoir is filled by water diverted from San Diego River during the winter months.

SAN DIEGO RIVER AT DIVERTING DAM NEAR LAKESIDE, CAL.

LOCATION.—In the NE. ¼ sec. 11, T. 14 S., R. 2 E., at the intake of San Diego flume, 1,000 feet below mouth of Boulder Creek, and about 13 miles northeast of Lakeside, San Diego County.

DRAINAGE AREA.—102 square miles (measured on topographic maps).

ELEVATION.—About 800 feet above sea level.

RECORDS AVAILABLE.—October 1, 1912 to January, 1916.

EXTREMES OF DISCHARGE.—1912–1915: Maximum stage recorded, 11.6 feet January 27, 1914, and March 20, 1915 (discharge, 2,380 second-feet); no flow over dam for several months during each year. The low-water discharge is diverted into San Diego flume.

DISCHARGE FOR JANUARY, 1916.—Mr. W. S. Post, consulting engineer for Cuyamaca Water Co., furnished the tables of discharge for the month of January, 1916. A rating curve has been developed by the Geological Survey covering the discharge to 2,400 second-feet. The discharge during the flood periods was computed from a weir formula for the dam.

STORAGE.—See Cuyamaca reservoir near Julian, Cal.

ACCURACY.—The maximum discharge for January, 1916, as determined by the weir formula, was checked by data on slope and cross section obtained after the flood.

Discharge, in second-feet, of San Diego River at diverting dam near Lakeside, Cal., for January, 1916.

Date.	Hour.	Instantaneous discharge.	Instantaneous Cuyamaca Waste.	Instantaneous discharge from 90 square miles.[a]
Jan. 13	6 a. m.	24	0	24
14	6 a. m.	24	0	22
	6 p. m.	28	0	28
15	6 a. m.	130	0	130
	6 p. m.	130	0	130
16	6 a. m.	130	0	130
	6 p. m.	349	0	349
17	6 a. m.	4,120	0	4,120
18	6 a. m.	4,710	0	4,710
	12 m	1,970	0	1,970
19	6 a. m.	1,970	110	1,860
	12 m	2,190	110	2,080
	6 p. m.	1,560	110	1,450
	12 p. m.	7,030	110	6,920
20	6 a. m.	1,070	110	960
	12 m	1,070	110	960
	6 p. m.	350	110	240
21	6 a. m.	526	106	420
	6 p. m.	540	0	540
22	6 a. m.	346	0	346
	6 p. m.	271	0	271
23	6 a. m.	205	0	205
		205	0	205
24	6 a. m.	203	0	203
	6 p. m.	283	0	283
25	6 a. m.	272	0	272
	6 p. m.	535	0	535
26	6 a. m.	1,230	40	1,190
	6 p. m.	528	0	528
27	6 a. m.	1,710	0	1,710
28	6 p. m.	15,800	900	14,900
29	12 m	5,800	700	5,100
30	12 m	3,240	400	2,840

[a] Does not include 12 square miles of drainage tributary to Cuyamaca reservoir.

Daily discharge, in second-feet, of San Diego River at diverting dam near Lakeside, Cal., for January, 1916.

Date.	Total discharge, including Cuyamaca waste.	Waste, Cuyamaca reservoir.	Total discharge from 90 square miles, exclusive of Cuyamaca basin.	Date.	Total discharge, including Cuyamaca waste.	Waste, Cuyamaca reservoir.	Total discharge from 90 square miles, exclusive of Cuyamaca basin.
Jan. 1–12	369	0	369	Jan. 22	276	0	276
13	36	0	36	23	205	0	205
14	54	0	54	24	264	0	264
15	147	0	147	25	509	11	498
16	1,581	0	1,581	26	929	23	906
17	4,410	0	4,410	27	10,200	820	9,380
18	2,655	33	2,622	28	10,900	1,877	9,023
19	1,815	106	1,709	29	5,910	815	5,095
20	727	106	621	30	3,070	550	2,520
21	409	65	343	31	2,227	345	1,882

Total run-off for month	acre-feet	92,800
	depth in inches on drainage area	17.06

SAN DIEGO RIVER AT CAPITAN GRANDE DAM SITE, NEAR LAKESIDE, CAL.

LOCATION.—1,000 feet upstream from the west line of sec. 8, T. 15 S., R. 2 E., in Capitan Grande Indian Reservation, about half a mile below mouth of Chocolate Creek, 1½ miles below mouth of South Fork of San Diego River, and 7¼ miles northeast of Lakeside, San Diego County.

DRAINAGE AREA.—189 square miles (measured on topographic map).

ELEVATION.—About 600 feet above sea level.

MAXIMUM DISCHARGE IN JANUARY, 1916.—J. F. Covert, chief engineer, Sweetwater Water Co., measured cross sections and slope at this point and computed the maximum discharge as follows:

FIRST SECTION.—Mean area, 2,151 square feet; mean wet perimeter, 205 feet; mean hydraulic radius, 10.5; slope, 0.0035; assumed value of n in Kutter's formula, 0.03; coefficient c, 74; mean velocity, 14.2 feet per second.

SECOND SECTION.—Mean area, 480 square feet; mean wet perimeter, 118 feet; mean hydraulic radius, 4.1; slope, 0.0035; assumed value of n in Kutter's formula, 0.035; coefficient c, 54; mean velocity, 6.5 feet per second.

Total discharge, 34,600 second-feet, or 183 second-feet per square mile of drainage area.

W. S. Post, consulting engineer for Cuyamaca Water Co., obtained the following flood data at approximately the same location (Pl. XI, *A*): Width, 187 feet; wet perimeter, 196 feet; area, 2,620 square feet; hydraulic radius, 13.4; slope, 0.0035 (in 1,600 feet). If the value of n in Kutter's formula is assumed as 0.035 the discharge is 38,000 second-feet, or 201 second-feet per square mile of drainage area. This discharge occurred during the afternoon of January 27. The crest reached Lakeside about 2 p. m.

SAN DIEGO RIVER NEAR SANTEE, CAL.

LOCATION.—In El Cajon grant at Mission dam, just above Oak Canyon, about half a mile below Spring Canyon, and 4½ miles west of Santee, San Diego County.

DRAINAGE AREA.—375 square miles (measured on topographic maps).

ELEVATION.—About 275 feet above sea level,.

RECORDS AVAILABLE.—May 25, 1912, to January, 1916.

EXTREMES OF DISCHARGE.—1912–1915: Maximum stage recorded, 13.6 feet February 11, 1915 (discharge, 3,960 second-feet); minimum stage, dry for several months each year except for the small amount of ground water rising to the surface at the dam.

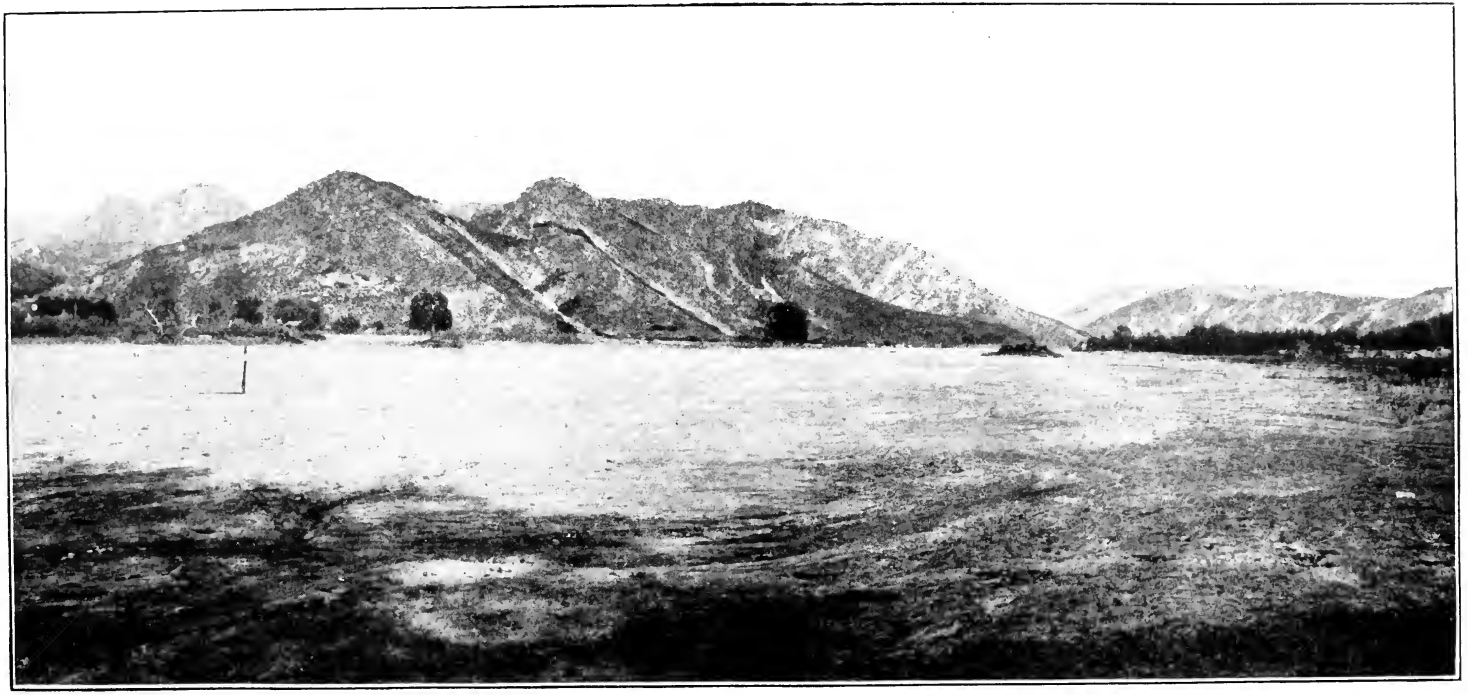
MAXIMUM DISCHARGE IN JANUARY, 1916.—On March 12, 1916, a cross section was taken 450 feet above the dam (Pl. XII, *A*). The channel, which is in sand, is straight for some distance above and below the section measured for slope. The high water removed practically all brush and trees along both banks and left the channel clean and smooth. It is believed that the remains of the old Mission dam acted as a control and prevented, at least to a considerable extent, the scour that would otherwise have occurred in the bed of the stream. On this account no allowance for scour has been made in computing the area at maximum stage.

The crest of the flood reached the gaging station during the afternoon of January 27. At Lakeside (Pl. XIII), 8½ miles upstream, it was reported that the crest occurred between 2 and 4 p. m. and at San Diego, 12½ miles downstream, at 7 p. m.

The maximum gage height at the dam was 25.1 feet (291.5 feet above sea level). The discharge is estimated as follows: Width, 310 feet; wet perimeter, 320 feet; area, 4,200 square feet; hydraulic radius, 13.1; slope of water surface on March 12, 1916, 0.0037 (for 875 feet). If the value of n in Kutter's formula is assumed as 0.03, the discharge was 70,200 second-feet, or 187 second-feet per square mile of drainage area.

A. VIEW UP SAN DIEGO RIVER AT MISSION DAM, NEAR SANTEE, AFTER FLOOD OF JANUARY, 1916.

B. VIEW UP MISSION VALLEY, SAN DIEGO RIVER, FROM OLD MUNICIPAL PUMPING PLANT, AFTER FLOOD OF JANUARY 1916.



VIEW UP CHANNEL OF SAN DIEGO RIVER AT LAKESIDE, AFTER FLOOD OF JANUARY, 1916.

Measurements of cross sections and slope, above and below Mission dam, made by J. F. Covert, engineer, Sweetwater Water Co., were used by F. C. Finkle, consulting engineer, to compute the maximum discharge, with the following results:

At Mission dam.—Mean area, 5,272 square feet; mean wet perimeter, 390 feet; mean hydraulic radius, 13.5; slope, 0.0027; assumed value of n in Kutter's formula, 0.03; coefficient c, 76.9; mean velocity, 14.7 feet per second; discharge, 77,390 second-feet.

Two miles below Mission dam.—Mean area, 4,884 square feet; mean wet perimeter, 286 feet; mean hydraulic radius, 17.1; slope, 0.0031; assumed value of n in Kutter's formula, 0.035; coefficient c, 69.7; mean velocity, 16.1 feet per second; discharge, 78,510 second-feet.

SAN DIEGO RIVER AT SAN DIEGO, CAL.

LOCATION.—At highway bridge in Block 391, Old Town subdivision, city of San Diego, San Diego County, and about 1½ miles above mouth (Pl. VII, *A*).

DRAINAGE AREA.—434 square miles (measured on topographic maps); 431 square miles at Murray Canyon ford, 2 miles upstream.

ELEVATION.—Practically sea level.

RECORDS AVAILABLE.—October 1, 1912, to January, 1916.

GAGE.—Inclined staff on left bank at bridge.

DISCHARGE MEASUREMENTS.—Made from concrete highway bridge until its failure at 2.20 p. m., January 27, 1916; after this date at the Atchison, Topeka & Santa Fe Railway bridge, a short distance below.

CHANNEL AND CONTROL.—Composed of sand; shifting.

EXTREME OF DISCHARGE.—1912–1915: Maximum stage recorded, 16.61 feet February 21, 1914 (approximate discharge, 9,500 second-feet); minimum stage, dry for several months during each year.

MAXIMUM DISCHARGE IN JANUARY, 1916.—The crest of the second flood occurred at 7 p. m., January 27. The discharge was estimated as 75,000 second-feet, or 173 second-feet per square mile.

ACCURACY.—On account of the shifting of the channel, the gage height record for periods not covered by discharge measurements is of little value. Daily discharge reported was computed from a hydrograph drawn through the discharge measurements and conforming in general shape with that determined for San Luis Rey River at Oceanside. The crest discharge on January 27, 1916, was estimated from the computed maximum discharge at Mission dam. Results considered fair.

Discharge measurements of San Diego River at San Diego, Cal., during January, 1916.

Date.	Made by—	Gage height.	Discharge.	Remarks.	
				Time of measurement.	Method.
		Feet.	*Sec.-ft.*		
Jan. 17	R. W. Day	13.55	10,400	9 a. m.	Floats.
17	do	13.45	10,100	10 a. m.	Do.
18	do	13.34	7,380	3 p. m.	Do.
19	Ellis and McFadden	12.1	8,650	Noon	Do.
20	do	9.1	2,180	11 a. m.	Do.
21	W. D. McFadden	7.8	1,820	Noon	Meter.
22	do	7.1	1,270	do	Do.
28	Ellis and Day	9.9	11,100	9 a. m.	Floats.
29	R. W. Day	9.98	6,560	11 a. m.	Do.

NOTE.—Mean velocities taken as 85 per cent of surface velocities obtained from floats.

Gage height, in feet, and discharge, in second-feet, of San Diego River at San Diego, Cal., for January, 1916.

Date.	Time.	Gage height.	Discharge.	Mean daily discharge.
Jan. 1–16				Drv.
17	9.30 a. m.	13.5	10,200	13,400
	12 p. m.	13.85	32,000	
18	3 p. m.	13.34	7,380	12,700
19	12 m.	12.1	8,650	7,320
20	11 a. m.	9.1	2,180	2,550
21	12 m.	7.8	1,820	1,760
22	12 m.	7.1	1,270	1,310
23	12 m.	7.3	1,400	1,380
24	10 a. m.	7.2	1,330	1,260
25	11 a. m.	6.9	1,130	1,280
26	11 a. m.	8.0	2,600	3,000
	4 p. m.	8.1	3,000	
27	7 a. m.	12.0	18,200	38,000
	3.30 p. m.	17.3	59,500	
	7 p. m.	19.3	75,000	
28	9 a. m.	9.9	11,100	13,200
29	11 a. m.	9.98	6,560	5,980
30				2,750
31				1,280
Total run-off for month	acre-feet			213,000
	depth in inches on drainage area			9.19

NOTE.—Water began flowing early in morning, Jan. 17; crest of first flood at midnight Jan. 17; crest of second flood at 7 p. m., Jan. 27. Concrete highway bridge failed at 2.20 p. m. Jan. 27.

BOULDER CREEK AT CUYAMACA RESERVOIR, NEAR JULIAN, CAL.

LOCATION.—In Cuyamaca grant, 12 miles above junction with San Diego River, and 7 miles south of Julian, San Diego County.

DRAINAGE AREA.—12 square miles, including area of reservoir, which is about 1 square mile (measured on topographic map).

ELEVATION.—About 4,650 feet above sea level.

RECORDS AVAILABLE.—June 19, 1912, to January, 1916. Records show only the amount of stored water released to supply San Diego flume.

RESERVOIR.—Cuyamaca dam, completed in 1886, was one of the first earth dams built in California for irrigation storage. The height, as originally constructed, was 35 feet. In 1894 the dam was enlarged, increasing the capacity of the reservoir to 11,400 acre-feet. The present dam is 635 feet long and 41½ feet high, having an upstream slope of 2:1 and a downstream slope of 1½:1. The water released from the reservoir flows down the natural channel of Boulder Creek and San Diego River to the intake of San Diego flume.

FLOOD DISCHARGE JANUARY, 1916.—W. S. Post, consulting engineer for Cuyamaca Water Co., computed the run-off, from the 11 square miles of drainage area tributary to the reservoir, for January 13 to 31, 1916. The estimates, which follow, are based upon very complete reports which give elevation of water surface in the reservoir, spillway discharge, rainfall records, etc.

Discharge, in second-feet, of Boulder Creek at Cuyamaca reservoir, near Julian, Cal., for January, 1916.

Date.	Hour.	Instantaneous discharge from 11 square miles.[a]	Instantaneous discharge per square mile.	Total discharge from 11 square miles.
Jan. 13	6 p. m	3	.....	3
14	6 p. m	59	5	59
15	6 p. m	125	11	125
16	6 p. m	534	48	534
17	6 p. m	865	79	865
18	6 p. m	456	41	456
19	6 p. m	0	.....	0
20	6 p. m	0	.....	0
21	6 p. m	20	2	20
22	6 p. m	39	3	39
23	6 p. m	32	3	32
24	6 p. m	29	3	29
25		0	.....	0
26	6 p. m	715	65	715
27	8 a. m	1,825	166	2,100
	10 a. m	1,671	152	.....
	6 p. m	2,393	217	.....
28	6 a. m	1,126	102	823
	6 p. m	383	35	.....
29	6 a. m	380	35	153
	6 p. m	200	17	.....
30	6 a. m	137	12	137
	6 p. m	88	8	.....
31	6 a. m	100	9	120
	6 p. m	95	9	.....

[a] Does not include precipitation on reservoir area, which is about 1 square mile.

Total run-off for month { acre-feet 12,300
depth in inches on drainage area 19.22

SAN VICENTE CREEK AT FOSTER, CAL.

LOCATION.—In sec. 31, T. 14 S., R. 1 E., about three-eighths of a mile above Foster, San Diego County, and 3¾ miles above junction with San Diego River.

DRAINAGE AREA.—74.9 square miles (measured on topographic map).

ELEVATION.—About 500 feet above sea level.

RECORDS AVAILABLE.—January 29 to April 4, 1915.

EXTREMES OF DISCHARGE.—1915: Maximum stage recorded, 6.5 feet February 11, 1915 (discharge, 1,190 second-feet); minimum stage, dry for several months during the year.

MAXIMUM DISCHARGE JANUARY, 1916.—On March 15, 1916, a cross section was measured 600 feet above abandoned gaging station (Pl. XI, *B*). The bed is composed of sand, fine gravel, and small boulders; channel clean except for trees and brush that grow along banks near the high water mark. The water was over the highway on left bank at the point where the cross-section was taken. The high-water slope was found to be 2.44 feet in 685 feet, which was somewhat less than the slope of the present water surface, owing probably to the slight contraction of the channel and curvature below. The channel is practically straight for the distance covered by the slope data.

The maximum discharge, which occurred January 27, is estimated as follows: Width, 190 feet; wet perimeter, 198 feet; area, 1,940 square feet; high water slope, .0036. If the value of n in Kutter's formula is assumed as .045, the discharge is 18,600 second-feet, or 248 second-feet per square mile of drainage area.

SWITZER CANYON AT SAN DIEGO, CAL.

The following information was furnished by Mr. George Cromwell, city engineer, San Diego, Cal.:

The drainage area of this stream above the point of measurement is 3.55 square miles: 1 square mile lies within the City Park and, except for a small part under cultivation, is in its original state as rough land covered with brush; and 2.55 square miles comprise subdivided residence property with graded streets. The maximum rate of run-off, which occurred at 7 a. m., January 27, 1916, was 668.5 second-feet, or 188 second-feet per square mile.

SAN DIEGUITO RIVER BASIN.

GENERAL FEATURES.

San Dieguito River, or Santa Ysabel Creek, as it is known from its source to the San Pasqual Valley, rises in the Volcan Mountains on the western slope of the Coast Range and flows westward through San Pasqual Valley, below which it takes its true name, and discharges into the Pacific Ocean midway between Oceanside and San Diego. Its length is 50 miles, and the maximum width of the drainage basin about 15 miles. The total drainage area is approximately 340 square miles. It lies south of San Luis Rey River and north of the San Diego River basin.

Numerous small tributaries enter Santa Ysabel Creek from its source to San Pasqual Valley, the most important being Black Canyon and Temescal creeks from the north and Santa Maria Creek from the south. Above the San Pasqual Valley the creek maintains a light flow throughout the year, but below that point the channel is dry during the summer months.

The upper part of the basin is rough, the surface being cut by many canyons. The lower part in the foothills is more rolling, with large areas of valley and high mesa land. The formation is a loose granite. The basin has very little timber, the principal cover being brush, grass, and a few scattered oaks.

The mean annual rainfall ranges from 10 to 15 inches along the foothills and from 20 to 40 inches in the mountains.

SANTA YSABEL CREEK NEAR MESA GRANDE, CAL.

LOCATION.—In the NW. ¼ sec. 21, T. 12 S., R. 2 E., at Sutherland dam site, about 1 mile below Sutherland, 1½ miles above mouth of Black Canyon Creek, and 4½ miles southwest of Mesa Grande, San Diego County.

DRAINAGE AREA.—53.4 square miles (measured on topographic map).

ELEVATION.—About 1,900 feet above sea level.

RECORDS AVAILABLE.—December 29, 1912, to January, 1916.

GAGE.—Friez water-stage recorder on right bank just above dam site; instrument was removed by flood January 27.

DISCHARGE MEASUREMENTS.—Made from cable at gage or by wading; equipment destroyed by the January flood.

CHANNEL AND CONTROL.—Shifting sand above and below station. A concrete control was constructed at an outcropping of bedrock 20 feet below gage. Banks are high, covered with brush, and not likely to be overflowed. Zero flow occurs at zero gage height.

EXTREMES OF DISCHARGE.—1912-1915: Maximum stage recorded, 4.53 feet February 11, 1915 (discharge, 1,040 second-feet); minimum stage dry October 1 and 2, 1913, August 12 to 29 and September 6 to 13, 1914.

MAXIMUM DISCHARGE IN JANUARY, 1916.—The maximum stage was 11.0 feet at noon January 27. Measurements of cross-section and slope made a short distance above Ramona-Mesa Grande highway bridge (Pl. XIV, *A*) and about a mile below gaging station on May 23, 1916, were furnished by W. S. Post, consulting engineer for Volcan Land & Water Co., as follows: Area, 1,180 square feet; wet perimeter, 149 feet; hydraulic radius, 7.9; high water slope from 500 feet above cross-section to 500 feet below, 0.02; width, 144 feet. If the value of n in Kutter's formula is assumed as 0.5 (channel composed of boulders and is rough), the discharge is 21,100 second-feet, or 395 second-feet per square mile of drainage area.

ACCURACY.—Results during flood period are considered fair. Water-stage recorder was in operation January 1 to 15 and 22 to 27. For the remainder of the month the staff gage was read once or twice daily.

The following discharge measurement was made by W. J. Isbell:

January 11, 1916: Gage-height, 1.04 feet; discharge, 35 second-feet.

Discharge, in second-feet, of Santa Ysabel Creek near Mesa Grande, Cal., for January, 1916.

Date.	Maximum.	Minimum.	Mean.	Date.	Maximum.	Minimum.	Mean.
Jan. 1			4	Jan. 17	10,600	1,550	4,130
2			10	18	6,500	2,500	4,200
3			12	19	3,660	1,940	2,580
4			9	20	1,940	650	1,280
5			10	21			500
6			10	22			480
7			9.5	23			225
8			8	24			200
9			18	25	660	200	416
10			62	26	460	350	406
11			45	27	21,100	400	10,800
12			19	28	8,550	2,400	4,720
13			15	29	2,400	1,000	1,520
14			36	30			800
15			54	31			560
16	1,750	50	405				

Total run-off for month { acre-feet 66,400
depth in inches on drainage area 23.29

SANTA YSABEL CREEK NEAR RAMONA, CAL.

LOCATION.—In the NE. ¼ sec. 27, T. 12 S., R. 1 E., at Pamo Camp, 1 mile below mouth of Temescal Creek, and about 4 miles north of Ramona, San Diego County.

DRAINAGE AREA.—110 square miles (measured on topographic map).

ELEVATION.—About 925 feet above sea level.

RECORDS AVAILABLE.—February 5, 1912, to January, 1916.

GAGE.—Staff in four sections on left bank, with a short vertical section at concrete control for use during extreme low water. Read three times a day and more frequently during high water. Destroyed by high water January 16. Observations for the remainder of the month were made by setting stakes at water surface and later referring them to gage datum by leveling. New staff was installed January 31 at proposed dam site about half a mile down stream.

DISCHARGE MEASUREMENTS.—Made from cable at gage or by wading. Cable was washed out on January 17, reinstalled January 26, and again destroyed January 27.

CHANNEL AND CONTROL.—Composed of sand and some boulders; somewhat shifting. On November 19, 1912, a concrete control was built about 30 feet below gage. The floods January 17 and 27, 1916, formed an entirely new channel to left of control.

EXTREMES OF DISCHARGE.—1912–1915: Maximum stage recorded, 8.05 feet, February 11, 1915 (discharge, 3,330 second-feet); minimum stage, 0.74 foot, October 1 to 6, 1915 (discharge, 0.1 second-foot).

MAXIMUM DISCHARGE IN JANUARY, 1916.—Measurements of cross section and slope data were made March 14, 1916, about half a mile below gaging station (Pl. XIV, *B*). The channel, which is composed of large boulders, gravel, and sand, is a little rough, and is clean, except for a few small willows. It is slightly curved between points covered by slope data. The maximum discharge, which occurred at 7 p. m. January 27, has been computed as follows: Width, 271 feet; wet perimeter, 276 feet; area, 2,070 square feet; hydraulic radius, 7.5; slope of present water surface, 0.0067 (for 455 feet). If the value of n in Kutter's formula is assumed as 0.035, the discharge is 28,400 second-feet, or 258 second-feet per square mile of drainage area.

The crest of the flood at 9 p. m., January 17, estimated from the Mesa Grande record, was 14,300 second-feet.

ACCURACY.—Results considered approximate. The gage-height records January 1 to 15 were lost during the flood. Discharge for this period estimated from Mesa Grande record and hydrographer's notes. Discharge January 16 to 30 computed from a hydrograph defined by discharge measurements and computed discharge, and having the general shape of the hydrograph for Santa Ysabel Creek near Mesa Grande.

Discharge measurements of Santa Ysabel Creek near Ramona, Cal., for January and February, 1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Jan. 11	W. J. Isbell	1.83	69	Feb. 1	W. D. McFadden	4.80	[a] 742
26	W. D. McFadden	2.50	531				

[a] Float measurement.

Mean daily discharge, in second-feet, of Santa Ysabel Creek near Ramona, Cal., for January, 1916.

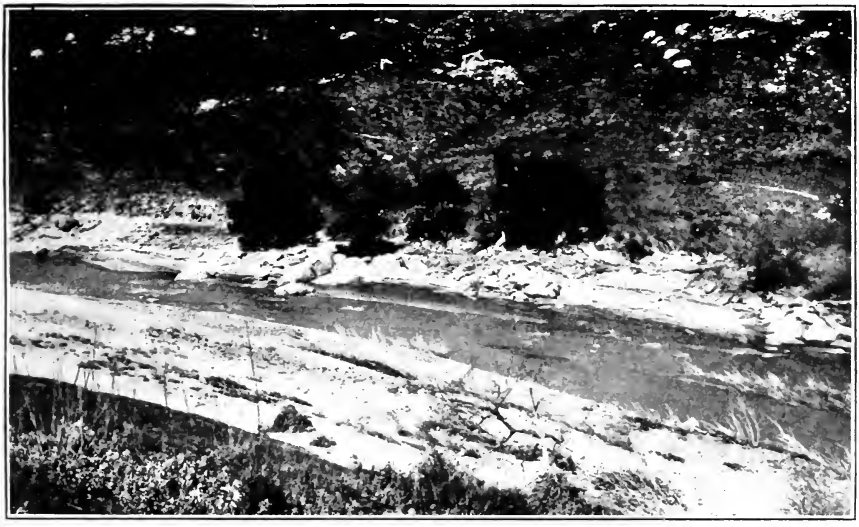
Day.	Discharge.	Day.	Discharge.	Day.	Discharge.	Day.	Discharge.
Jan. 1	7	Jan. 9	28	Jan. 17	6,060	Jan. 25	668
2	17	10	95	18	7,420	26	611
3	20	11	69	19	3,680	27	14,100
4	15	12	29	20	2,110	28	9,740
5	17	13	23	21	865	29	2,540
6	17	14	55	22	560	30	1,160
7	15	15	81	23	450	31	865
8	12	16	664	24	400		

Total run-off for month { acre-feet 104,000
depth in inches on drainage area 17.75

SAN DIEGUITO RIVER NEAR BERNARDO, CAL.

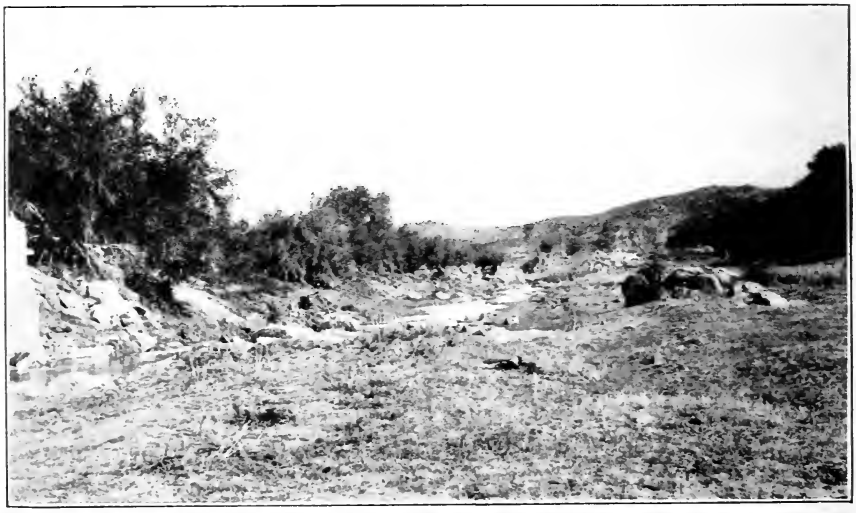
LOCATION.—In the SE. ¼ NW. ¼ sec. 18, T. 13 S., R. 2 W., at Carroll dam site, 5½ miles downstream from former station at Bernardo bridge, about 10½ miles above mouth of river, and 4 miles southwest of Bernardo, San Diego County.

A. VIEW UPSTREAM ON SANTA YSABEL CREEK NEAR MESA GRANDE, AFTER FLOOD OF JANUARY, 1916.



B. VIEW ACROSS SANTA YSABEL CREEK NEAR RAMONA, AFTER FLOOD OF JANUARY, 1916.

A. VIEW DOWNSTREAM ON SAN DIEGUITO RIVER AT CARROLL DAM SITE, NEAR BERNARDO, AFTER FLOOD OF JANUARY, 1916.



B. VIEW DOWNSTREAM ON SANTA MARIA CREEK NEAR RAMONA, IN 1917.

DRAINAGE AREA.—299 square miles (measured on topographic maps); 266 square miles for station at Bernardo.

ELEVATION.—About 150 feet above sea level.

RECORDS AVAILABLE.—April 17, 1912, to September 30, 1915, for station at Bernardo.

GAGE.—Vertical staff in 4 sections on right bank at dam site.

DISCHARGE MEASUREMENTS.—Equipment not yet installed. Wading measurements have been made at gage.

CHANNEL AND CONTROL.—Shifting sand with bed rock outcropping about 400 feet below gage (Pl. XV, *A*).

EXTREMES OF DISCHARGE.—1912–1915: Maximum stage recorded, 17.8 feet February 11, 1915 (discharge, 5,050 second-feet); minimum stage, practically dry for several months each year (for Bernardo station).

MAXIMUM DISCHARGE IN JANUARY, 1916.—The maximum stage was reported as 21.2 feet and occurred at from 1 p. m. to 3 p. m. January 27. Measurements of slope and two cross sections made at the dam site were furnished by W. S. Post, consulting engineer for Volcan Land & Water Co., as follows: Mean area, 4,870 square feet (correction was made for scour in channel as a profile of the bed rock was available); mean hydraulic radius, 17.25; high-water slope, 0.0033 (for 705 feet). If the value of n in Kutter's formula is assumed as 0.04, the discharge is 72,100 second-feet, or 241 second-feet per square mile of drainage area.

ACCURACY.—Discharge January 1 to 16 computed from records obtained at station at Bernardo. On January 17 the equipment at this station was destroyed and the channel greatly changed by the high water. For January 17 to 31, discharge record at Carroll dam site has been furnished by W. S. Post. These computations are based upon the gage-height record and rating curves defined by later measurements and flood discharge computed from data on cross section and slope. Mean daily discharge computed from hydrograph defined by these data and conforming in general shape to the hydrographs for other stations in the same and adjoining drainage basins.

Mean daily discharge, in second-feet, of San Dieguito River near Bernardo, Cal., for January, 1916.

Day.	Discharge.	Day.	Discharge.	Day.	Discharge.	Day.	Discharge.
Jan. 1	22	Jan. 9	32	Jan. 17	11,800	Jan. 25	1,060
2	22	10	45	18	27,000	26	2,950
3	27	11	257	19	14,800	27	37,200
4	22	12	100	20	5,220	28	15,100
5	22	13	82	21	1,730	29	4,750
6	32	14	74	22	909	30	2,200
7	32	15	230	23	662	31	1,220
8	32	16	1,310	24	708		

Total run-off for month { acre-feet 257,500
depth in inches on drainage area 16.14

NOTE.—Discharge, Jan. 1-16, is for former station at Bernardo. The run-off for this period for the area between Bernardo bridge and Carroll dam site is believed to be negligible.

SANTA MARIA CREEK NEAR RAMONA, CAL.

LOCATION.—In the SE. ¼ sec. 11, T. 13 S., R. 1 W., about 7 miles below mouth of Hatfield Creek, and 5½ miles west of Ramona, San Diego County.

DRAINAGE AREA.—57.3 square miles (measured on topographic map).

ELEVATION.—About 1,300 feet above sea level.

RECORDS AVAILABLE.—November 6, 1912 to January, 1916.

GAGE.—Friez water-stage recorder on right bank just above concrete control, with staff in two sections on opposite bank. Water-stage recorder was destroyed by January flood.

DISCHARGE MEASUREMENTS.—Made from cable 100 feet below gage or by wading; equipment was destroyed by the January flood.

CHANNEL AND CONTROL.—Shifting sand above and below station. Concrete control installed just below gage at an outcropping of solid rock. Zero flow occurs at a gage height of about 1.32 feet.

About 1,000 feet below gage, valley narrows to a rocky gorge at proposed dam site. There appears to be considerable natural storage in the channel at extreme high water. The slope of the water surface at maximum flood stage was found to be much less than at low or medium discharge.

EXTREMES OF DISCHARGE.—1912–1915: Maximum stage recorded, 7.05 feet February 10, 1915 (discharge 1,890 second-feet); minimum stage, dry for several months each year.

MAXIMUM DISCHARGE IN JANUARY, 1916.—Measurements of slope and cross section were made at the gaging station (Pl. XV, *B*) on March 14, 1916. The cross section was taken 315 feet below staff gage. The channel, which is composed principally of sand, is straight and clean except for a few trees on left bank below gage. About 1,000 feet below station valley narrows to a rock gorge which causes some natural storage in the channel during flood stages. The maximum gage height, as determined from flood marks, was 15.9 feet and occurred at about 5 p. m. January 27. The maximum discharge has been computed as follows: Width, 238 feet; wet perimeter, 242 feet; area, 2,040 square feet; hydraulic radius, 8.4; slope of water surface at maximum stage, 0.00037 (for 1,010 feet). The slope of the water surface March 14 was 0.0059 (for 575 feet). If the value of n in Kutter's formula is assumed as 0.035, the discharge is 7.140 second-feet, or 125 second-feet per square mile or drainage area.

ACCURACY.—Results considered reliable. Gage was read two to six times a day during high water. The concrete control was not injured by the flood.

Discharge measurements of Santa Maria Creek near Ramona, Cal., for January and February, 1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Jan. 4	W. J. Isbell	1.37	0.1	Jan. 24	W. D. McFadden	2.70	75
11	do	1.80	2.4	Feb. 3	Day and McFadden	3.45	144

Discharge, in second-feet, of Santa Maria Creek near Ramona, Cal., for January, 1916.

Date.	Maximum.	Minimum.	Mean.	Date.	Maximum.	Minimum.	Mean.
Jan. 1			0.2	Jan. 17	3,720	2,210	2,820
2			.2	18	3,310	1,280	1,960
3			.2	19	1,280	518	914
4			.0	20	518	178	283
5			.0	21	178	150	163
6			.0	22	150	90	113
7			.0	23	90	71	78
8			.2	24	71	71	71
9			.2	25	816	71	275
10			.4	26	3,360	816	1,970
11			2.4	27	7,140	2,880	4,960
12			1.5	28	2,880	430	1,370
13			1.0	29	430	112	223
14			2.5	30	410	208	322
15			4.0	31	208	136	150
16			1,200				

Total run-off for month { acre-feet 33,500
depth in inches on drainage area 10.96

NOTE.—Discharge January 4 to 7 less than 0.1 second-foot.

SAN LUIS REY RIVER BASIN.

GENERAL FEATURES.

San Luis Rey River drains an area comprising 565 square miles lying wholly in the northern part of San Diego County and extending from the crest of the Coast Range to the Pacific Ocean, a distance of 65 miles, with a maximum width of about 16 miles.

The river is formed by many small streams which rise in the higher elevations of the Coast Range and come together at the lower or west end of what is known as Warner's valley. Below this point the river flows for a distance of 10 miles through a deep narrow canyon with a heavy grade, then over a sandy and gravelly bed with medium grade for some 40 miles, finally discharging into the Pacific Ocean at Oceanside.

Altitudes within this basin range from 50 to 500 feet in the foothills in the vicinity of Oceanside and from 500 to 6,000 feet on the mountains. Palomar Mountain, the highest peak in the basin, is 6,126 feet above sea level. The upper portion of the basin is more or less rolling, and several of the valleys are under cultivation and are used extensively for stock raising; the middle part, occupied by the river in its canyon, is rough; on the lower reaches the surface becomes less rugged, merging into the foothills, which extend to the coast. The rocks are granitic.

The basin is poorly forested. Some fairly good timber is found on the higher elevations, but the greater part of the cover is brush and grass with a scattered growth of oaks.

The mean annual precipitation in this basin ranges from about 10 to 50 inches, gradually increasing with altitude. It occurs almost entirely as rain, snow appearing only occasionally on the high elevations.

SAN LUIS REY RIVER NEAR MESA GRANDE, CAL.

LOCATION.—In the NE. ¼ sec. 9, T. 11 S., R. 2 E., 1 mile below Warner dam site and mouth of Carrizo Creek, and about 5 miles north of Mesa Grande, San Diego County.

DRAINAGE AREA.—209 square miles (measured on topographic and military survey maps).

ELEVATION.—About 2,650 feet above sea level.

RECORDS AVAILABLE.—October 3, 1911 to January 1916.

GAGE.—Barrett & Lawrence water-stage recorder on left bank just above concrete weir; destroyed by high water during night, January 16, 1916. Staff gage at same location and datum as water-stage recorder read frequently January 17 to 31 by an engineer of the Volcan Land & Water Co.

DISCHARGE MEASUREMENTS.—Made from cable about a mile above gage or by wading.

CHANNEL AND CONTROL.—Composed of sand and gravel; somewhat shifting. The concrete weir which acted as a control was practically destroyed by the high water.

EXTREMES OF DISCHARGE.—1911–1915: Maximum stage recorded, 7.5 feet February 21, 1914 (discharge 3,470 second-feet); minimum stage, 0.09 foot August 31, 1914 (discharge, estimated, 0.2 second-foot).

MAXIMUM DISCHARGE IN JANUARY, 1916.—Measurements of cross sections and slope made a short distance below dam site, were furnished by W. S. Post, consulting engineer, for Volcan Land & Water Co., as follows:

Mean area, 2,960 square feet; mean wet perimeter, 242 feet; mean hydraulic radius, 12.2; high water slope over 900-foot range (from 300 feet above to 600 feet below cable), 0.0073. If the value of n in Kutter's formula is assumed as 0.035, the discharge is 58,600 second-feet, or 280 second-feet per square mile of dranage area. No correction was made to the area for probable scour in channel at crest of flood.

ACCURACY.—Results considered good. Gage read frequently except during night.

Discharge measurements of San Luis Rey River near Mesa Grande, Cal., during January, 1916.

Made by W. J. Isbell.

Date.	Gage height.	Discharge.	Time of measurement.	Date.	Gage height.	Discharge.	Time of measurement.
	Feet.	*Sec-ft.*			*Feet.*	*Sec-ft.*	
Jan. 1	0.35	16	.....	Jan. 18	9.06	[a] 9,850	11 a. m.
3	.42	24	9 a. m.	19	5.44	2,630	3 p. m.
7	.39	21	4 p. m	23	1.78	364	11 a. m.
9	.85	103	11 a. m	26	2.38	[a] 561	10 a. m.
16	1.58	248	11 a. m	28	6.70	[a] 3,830	11 a. m.

[a] Made from cable.

Discharge, in second-feet, of San Luis Rey River near Mesa Grande, Cal., for January, 1916.

Date.	Maximum.	Minimum.	Mean.	Date.	Maximum.	Minimum.	Mean.
Jan. 1	.....	.....	16	Jan. 17	24,400	4,800	13,000
2	.....	.....	25	18	15,600	4,350	10,100
3	.....	.....	24	19	4,350	1,580	2,740
4	.....	.....	20	20	1,580	595	896
5	.....	.....	29	21	595	478	536
6	.....	.....	36	22	478	390	428
7	.....	.....	21	23	390	325	352
8	.....	.....	16	24	425	325	354
9	.....	.....	103	25	1,190	355	775
10	.....	.....	40	26	1,990	425	806
11	.....	.....	42	27	58,600	1,990	28,100
12	.....	.....	43	28	21,700	2,130	6,130
13	.....	.....	44	29	3,200	1,630	2,060
14	.....	.....	46	30	2,770	1,160	1,610
15	.....	.....	170	31	1,160	895	1,020
16	5,300	210	1,550				

Total run-off for month { acre-feet 141,000
depth in inches on drainage area 12.68

NOTE.—Crest of flood Jan. 17 occurred at 1.45 p. m., gage height 12.8 feet; January 27 at 4.30 p. m., gage height 18.0 feet.

SAN LUIS REY RIVER NEAR NELLIE, CAL.

LOCATION.—In Potrero Indian Reservation (near west line of sec. 33, T. 10 S., R. 1 E., unsurveyed), 500 feet above intake of Escondido Mutual Water Co.'s canal, 8 miles below gaging station at Warner dam site near Mesa Grande, and about 4½ miles southwest of Nellie, San Diego County.

DRAINAGE AREA.—240 square miles (measured on topographic and military-survey maps).

ELEVATION.—About 1,800 feet above sea level.

GAGE.—Friez water-stage recorder on left bank, with reinforced concrete well, 500 feet above intake of Escondido Mutual Water Co.'s canal; equipment destroyed by January flood.

DISCHARGE MEASUREMENTS.—Made from cable 400 feet above gage or by wading; equipment destroyed by January flood.

CHANNEL AND CONTROL.—Composed of sand and boulders overlying solid rock. A concrete control, extending to bedrock, was built across channel about 30 feet below gage.

ACCURACY.—Record for January considered approximate. No gage-height record available, except January 1 to 8, as water-stage recorder was destroyed by the flood. Discharge January 9 to 14 estimated from Mesa Grande record, that for rest of month estimated from flood studies at Mesa Grande, records at Oceanside, and mean rainfall computed for drainage area.

Discharge measurements of San Luis Rey River, near Nellie, Cal., for January, 1916.

[Made by W. J. Isbell.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Jan. 8	1.30	22	Jan. 22	3.02	571
15	2.30	194			

Mean daily discharge, in second-feet, of San Luis Rey River near Nellie, Cal., for January, 1916.

Date.	Discharge.	Date.	Discharge.	Date.	Discharge.	Date.	Discharge.
Jan. 1	25	Jan. 5	38	Jan. 9	140	Jan. 13	60
2	43	6	48	10	55	14	63
3	41	7	29	11	58	15	194
4	26	8	22	12	59		

Total run-off for month { acre-feet 165,000
depth in inches on drainage area 12.91

SAN LUIS REY RIVER NEAR PALA, CAL.

LOCATION.—Above ford on road to Sickler's mill, in the NW. ¼ sec. 31, T. 9 S., R. 1 W., about 4 miles southeast of Pala, San Diego County.

DRAINAGE AREA.—322 square miles (measured on topographic and military-survey maps).

ELEVATION.—About 575 feet above sea level.

RECORDS AVAILABLE.—October 9, 1903 to June 30, 1911, and November 14, 1912, to January, 1916.

GAGE.—Friez water-stage recorder on left bank 600 feet above ford. Previous to September 19, 1912, records were obtained from staff gage about 50 feet above ford. November 13, 1906, original gage datum was lowered 4.66 feet. Present gage is at an independent datum. Water-stage recorder was removed by high water in January; no record after January 16, 1916.

DISCHARGE MEASUREMENTS.—Made from cable 550 feet below water-stage recorder or by wading.

CHANNEL AND CONTROL.—Composed of sand, gravel, and boulders; shifting. An artificial control, consisting of short concrete cut-off walls between the boulders, was rebuilt across the channel just below gage on September 28, 1914, and was destroyed by flood of January, 1916. Stage of zero flow for new control. about 5.7 feet.

EXTREMES OF DISCHARGE.—1905–1915: Maximum stage recorded, 12.0 feet (original datum) at noon and at 2 p. m. March 24, 1906 (discharge, 22,000 second-feet); minimum stage, 5.28 feet August 6 and 7, 1907 (discharge, 0.6 second-foot).

MAXIMUM DISCHARGE IN JANUARY, 1916.—Maximum stage reached during flood was 18.1 feet, as determined by leveling from high-water mark. Maximum discharge was approximately 75,000 second-feet (see San Luis Rey at Pala).

ACCURACY.—Results January 1 to 16 considered good; no gage-height record after January 16, as equipment was destroyed. Discharge January 17 to 31 estimated from flood studies of Mesa Grande and Oceanside records, and mean rainfall computed for drainage area.

Mean daily discharge, in second-feet, of San Luis Rey River near Pala, Cal., for January, 1916.

Date.	Discharge.	Date.	Discharge.	Date.	Discharge.	Date.	Discharge.
Jan. 1	18	Jan. 5	18	Jan. 9	34	Jan. 13	99
2	18	6	26	10	119	14	92
3	27	7	25	11	289	15	311
4	18	8	18	12	161	16	1,660

Total run-off for month	acre-feet	201,000
	depth in inches on drainage area	11.76

SAN LUIS REY RIVER AT PALA, CAL.

LOCATION.—300 feet above intake of South Side Pala Indian ditch, below Agua Tibia Creek, 1½ miles below Geological Survey gaging station, and about 1½ miles southeast of Pala, San Diego County.

DRAINAGE AREA.—322 square miles (at Geological Survey gaging station, 1½ miles upstream, measured on topographic and military-survey maps).

ELEVATION.—About 500 feet above sea level.

FLOOD DISCHARGE FOR JANUARY, 1916.—About 30 days after the flood, Mr. C. H. Southworth, United States Indian Irrigation Service, measured cross-section and slope at this point and computed the maximum discharge for January 27, as follows: Area, 2,690 square feet; wet perimeter, 300 feet; hydraulic radius, 8.9; slope, 0.012; assumed value of n inKutter's formula, 0.025; mean velocity, 28.0 feet per second; discharge, 75,300 second-feet.

SAN LUIS REY RIVER AT BONSALL, CAL.

LOCATION.—In the SW. ¼ sec. 20, T. 10 S., R. 3 W., at concrete highway bridge at Bonsall, San Diego County, just above Moosa Canyon, about 14 miles below gaging station near Pala, and 14 miles above mouth of river.

DRAINAGE AREA.—465 square miles (measured on topographic and military survey maps).

ELEVATION.—About 150 feet above sea level.

RECORDS AVAILABLE.—April 16, 1912, to January, 1916.

GAGE.—Staff in three sections on left bank at bridge; read twice daily. Previous staff was on left bank, 150 feet below present gage. Original datum not maintained.

DISCHARGE MEASUREMENTS.—Made from bridge at gage or by wading.

CHANNEL AND CONTROL.—Composed of sand; shifting.

EXTREMES OF DISCHARGE.—1912–1915: Maximum stage recorded, 7.0 feet February 11, 1915 (discharge 9,000 second-feet); channel dry for several months each year.

MAXIMUM DISCHARGE IN JANUARY, 1916.—Gage and highway bridge destroyed by high water; no record after January 15. Maximum discharge not estimated owing to instability of channel.

ACCURACY.—Results January 1 to 15 considered fair. Discharge for remainder of month estimated from flood studies of Mesa Grande and Oceanside records and mean rainfall computed for drainage area.

Mean daily discharge, in second-feet, of San Luis Rey River at Bonsall, Cal., for January, 1916.

Date.	Discharge.	Date.	Discharge.	Date.	Discharge.	Date.	Discharge.
Jan. 1	57	Jan. 5	42	Jan. 9	57	Jan. 13	86
2	57	6	42	10	95	14	86
3	57	7	57	11	320	15	268
4	57	8	57	12	162		

Total run-off for month { acre-feet 257,000
depth in inches on drainage area 10.36

SAN LUIS REY RIVER AT OCEANSIDE, CAL.

LOCATION.—In the SE. ¼ NE. ¼ sec. 22, T. 11 S., R. 5 W., at highway bridge about half a mile above mouth, at Oceanside, San Diego County.

DRAINAGE AREA.—565 square miles (measured on topographic and military survey maps); for gaging station opposite Oceanside pumping plant, 1½ miles upstream, 563 square miles.

ELEVATION.—Sea level.

RECORDS AVAILABLE.—April 17, 1912, to September 30, 1915, for station opposite Oceanside pumping plant.

DISCHARGE MEASUREMENTS.—Made from concrete highway bridge until its failure at 9.30 p. m., January 27, 1916. Later measurements were made from a boat at approximately the same location (Pl. VIII, *A*, p. 32).

CHANNEL AND CONTROL.—Composed of sand; shifting. The discharge measurement made at 6 p. m., January 27, 1916, indicated that the scour in the main channel amounted to about 10 feet as compared with the cross section measured May, 25 1916.

EXTREMES OF DISCHARGE.—1912–1915: Maximum stage recorded at station opposite Oceanside pumping plant, 4.9 feet February 11, 1915 (approximate discharge, 7,000 second-feet); channel dry for several months during each year.

MAXIMUM DISCHARGE IN JANUARY, 1916.—The crest discharge of the flood on January 17, 1916, was estimated from the Mesa Grande record, using the ratio that obtained for the flood of January 27, at 40,000 second-feet. The crest discharge, which occurred at 9.30 p. m. January 27, was estimated as follows: From a study of the cross section measured May 25 and the measurement at 6 p. m. January 27, it is evident that the maximum stage at 9.30 p. m. was at least 3.0 feet higher than at the time of the measurement. At the pumping plant, 1½ miles upstream, where the channel is much wider, a rise of more than 2 feet was reported. Low tide occurred at 7.15 p. m. January 27; hence the maximum stage was not affected by the tide. Without making any allowance for additional scour in the channel, the area at maximum stage would be 1,860 square feet greater than at 6 p. m., or a total area of 6,370 square feet. The mean velocity has been estimated as 15 feet per second. For the measurement at 6 p. m. it was 12.3 feet per second. The estimated maximum discharge is 95,600 second-feet, or 169 second-feet per square mile.

ACCURACY.—Mean daily discharge January 16 to 31, 1916, computed from a hydrograph based on discharge measurements and compared with the records on San Luis Rey River near Mesa Grande. Results considered fair.

Discharge measurements of San Luis Rey River at Oceanside, Cal., for January, 1916.

Date.	Made by—	Gage height.	Discharge.	Remarks.	
				Time of measurement.	Method.
1916.		*Feet.*	*Sec.-ft.*		
Jan. 16	McFadden and Ireland	2.45	216	9 a. m.	
17	Strout and Ireland	6.0	27,100	3 p. m.	Meter and floats.
18	.....do	4.0	16,200	9 a. m.	Floats.
18	.....do	4.0	20,800	3 p. m.	Do.
19	.....do	3.0	9,990	9 a. m.	Do.
19	.....do	2.5	9,080	4 p. m.	Do.
20	.....do	2.0	3,690	10 a. m.	Do.
21	.....do	1.8	2,000	9 a. m.	Meter.
22	C. B. Ireland	1.4	1,650	11 a. m.	Do.
22	.....do	1.4	1,480	4 p. m.	Do.
23	.....do	1.3	1,460	9 a. m.	Do.
23	.....do	1.3	1,240	4 p. m.	Do.
24	.....do	1.3	1,150	9 a. m.	Do.
24	.....do	1.3	1,030	4 p. m.	Do.
25	.....do	1.4	1,310	9 a. m.	Do.
25	.....do	1.5	1,580	4 p. m.	Do.
26	.....do	1.6	1,800	9 a. m.	Do.
27	Strout and Ireland	.....	9,640	10 a. m.	Floats.
27	.....do	.....	55,400	6 p. m.	Do.
28	Strout and Bowen	.....	21,900	9 a. m.	Do.
30	G. S. Strout	.....	2,190	4 p. m.	Do.
31	.....do	.....	1,260	4 p. m.	Do.

NOTE.—Mean velocities taken as 80 per cent of surface velocities obtained from floats.

Discharge, in second-feet, of San Luis Rey River at Oceanside, Cal., for January, 1916.

Date.	Maximum.	Minimum.	Mean.	Date.	Maximum.	Minimum.	Mean.
Jan. 16	6,500	216	2,180	Jan. 24	1,200	1,030	1,110
17	40,000	10,000	20,800	25	1,600	1,100	1,400
18	21,500	13,500	18,100	26	3,800	1,600	2,230
19	13,500	5,700	9,640	27	95,600	3,800	33,800
20	5,700	2,400	3,730	28	85,000	7,700	28,200
21	2,400	1,700	1,980	29	7,700	3,700	5,330
22	1,700	1,480	1,590	30	3,700	1,800	2,650
23	1,480	1,200	1,350	31	1,800	1,170	1,430

Total run-off for period { acre-feet 269,000
depth in inches on drainage area 8.92

MOOSA CANYON CREEK NEAR BONSALL, CAL.

LOCATION.—Near the northwest corner of sec. 1, T. 11 S., R. 3 W., at Moose dam, half a mile below mouth of South Fork, and 4½ miles southeast of Bonsall, San Diego County.

DRAINAGE AREA.—31 square miles (measured on topographic map by John F. Covert).

ELEVATION.—About 400 feet above sea level.

MAXIMUM DISCHARGE IN JANUARY, 1916.—John F. Covert, chief engineer Sweetwater Water Co., estimated the discharge over the dam to be 8,346 second-feet. The maximum stage 100 feet upstream from the dam, determined December 15, 1916, from flood marks was 9.1 feet above crest of dam. The concrete dam is 81 feet long on top and the width of the canyon at a point 9.1 feet above the crest is 105 feet.

SANTA ANA RIVER BASIN.

GENERAL FEATURES.

Of the three principal streams that traverse the valley of southern California—Santa Ana, San Gabriel, and Los Angeles rivers—the Santa Ana is the largest. Its drainage basin, lying south of the San Bernardino Mountains and the Sierra Madre and taking waters from their southern slopes, is the most easterly and comprises by far the largest area, including the northern part of Orange County, the northwestern part of Riverside County, and the southwestern part of San Bernardino County. Of the total drainage area, covering between 1,800 and 1,900 square miles, about two-thirds is in the valley, but only a few hundred square miles yields much run-off.

The Santa Ana rises in the heart of the San Bernardino Mountains, about 30 miles east of Highland, and flows westward for about 25 miles to the mouth of its upper canyon; thence southwestward across San Bernardino Valley, through the lower canyon in the Santa Ana Mountains, and across the coastal plain to the Pacific Ocean at Newport Beach. Although the course of the stream measures about 100 miles, there is continuous surface flow from mountain to sea only during winter floods.

Many small streams from the southern slope of the San Bernardino Mountains and a few from the Sierra Madre west of the Cajon Pass flow toward the Santa Ana, but some of these discharge water to the main stream only in the flood seasons, the ordinary flow either being diverted or sinking into the sand and gravel of San Bernardino Valley. The principal tributaries are Bear, Alder, Mill, Lytle, and Chino creeks.

Altitudes in the Santa Ana drainage area range from a few feet above sea level on the coastal plain to 2,000 or 3,000 feet on the Santa Ana Mountains, 500 to 1,200 feet in the San Bernardino basin, and 2,000 to 11,000 feet on the southern slope of the San Bernardino Mountains. The more elevated regions are rough and rugged, and the mountain sides are incised by many canyons which are the result of active stream erosion. The rocks are granitic. The mesa and valley lands at the base of the mountains are composed of granitic gravel and sand of great depth. The higher mountain slopes support considerable timber; most of the lower slopes are covered with brush and grass.

The mean annual precipitation varies considerably in different parts of the Santa Ana basin. On the coastal plain west of the Santa Ana Range it averages 10 inches or more; eastward, in the San Bernardino Valley, it amounts to from 10 to 16 inches. On the mountain slopes it ranges from 20 inches at the base to 40 inches or more near the crest, and in Bear Valley north of the highest peaks, such

as San Bernardino and San Gorgonio, it may be even 50 inches. Considerable snow falls in the region of these high peaks in winter and remains well into the summer, especially on the northern slopes, from which the headwaters of the Santa Ana come.

SANTA ANA RIVER NEAR MENTONE, CAL.

LOCATION.—In the SW. ¼ sec. 4, T. 1 S., R. 2 W., just above mouth of canyon, one-fourth mile above Pacific Light & Power Corporation's plant, one-half mile above mouth of Deep Creek, and 3½ miles northeast of Mentone, San Bernardino County.

DRAINAGE AREA.—189 square miles (measured on topographic maps).

ELEVATION.—About 1,900 feet above sea level.

RECORDS AVAILABLE.—July 1, 1896, to January, 1916.

GAGE.—Vertical staff fastened to rock ledge on left bank one-fourth mile above power house; read daily. Destroyed by high water during night of January 17–18; no record obtained during rest of month.

DISCHARGE MEASUREMENTS.—Car and cable at Warm Springs Canyon destroyed by flood. On account of the damage to the highways and bridges it was impossible to reach this station for several days after the flood had passed.

CHANNEL AND CONTROL.—Composed of gravel and boulders; very rough; shifts during high water.

EXTREMES OF DISCHARGE.—1896–1915: Crest gage height January 1, 1910, not known, as gage was destroyed (mean discharge for day estimated as 8,500 second-feet); minimum stage, 2.3 feet during parts of every month from October, 1913, to January, 1915 (discharge, 0.6 second-foot).

MAXIMUM DISCHARGE IN JANUARY, 1916.—As the gage was destroyed during the night of January 17–18, there is no record of stage for the month after 8 a. m. January 17. Slope cross section measured at the gaging station March 8, 1916 (Pl. XVI, *A*). The cross section was measured just below temporary highway bridge, 357 feet below gage. The channel, which is composed of large and small boulders, sand, and gravel, is clean and very rough. The slope of the water surface at maximum stage was determined for a distance of 1,620 feet, where the channel was generally straight. The maximum discharge has been computed as follows: Width, 510 feet; wet perimeter, 526 feet; area, 2,290 square feet; hydraulic radius, 4.4; slope of water surface (flood stage), 0.024 (for 1,620 feet). If the value of n in Kutter's formula is assumed as 0.05, the discharge is 29,100 second-feet, or 154 second-feet per square mile of drainage area.

For purpose of comparison it is interesting to note that the intake of the Mentone power plant, operator's house, and other structures removed by this flood had been in place since the plant was constructed in 1902. Also that a large number of trees, 2 feet in diameter, were brought down by the high water. During the flood the river at the mouth of the canyon, would swing from one side of the canyon to the other and back again, within an hour, the action being due to jams formed by great numbers of large boulders moving downstream.

DIVERSIONS.—The intake of the Pacific Light & Power Corporation's canal is at Southern California Edison Co. plant No. 2, 2½ miles above the gage. The intake of this canal was washed out at 8.40 a. m. January 17, 1916. No water was diverted through it during the rest of the month.

REGULATION.—Water is stored on Bear Creek at Bear Valley reservoir.

SANTA ANA RIVER AT SAN BERNARDINO, CAL.

LOCATION.—At Salt Lake Street Bridge (E Street), San Bernardino, San Bernardino County.

MAXIMUM DISCHARGE IN JANUARY, 1916.—Mr. H. B. Andrews, Riverside Water Co., who measured cross section and slope, from high-water marks which he observed

A. GAGING STATION ON SANTA ANA RIVER NEAR MENTONE, AFTER FLOOD OF JANUARY, 1916.

B. VIEW ACROSS CHANNEL OF SAN GABRIEL RIVER AT MOUTH OF CANYON, NEAR AZUSA, AFTER FLOOD OF JANUARY, 1916.

A. VIEW UPSTREAM ON SAN JACINTO RIVER NEAR ELSINORE, AFTER FLOOD OF JANUARY, 1916.

B. VIEW EASTWARD ALONG NORTH SHORE OF ELSINORE LAKE, MARCH 10, 1916.

during the storm of January 17, has estimated the discharge as follows: Area, 2,020 square feet; wet perimeter, 251 feet; slope, 0.006; discharge, 40,000 second-feet. The high-water marks on January 27 were practically the same as for January 17.

The following discharge measurements at Salt Lake Street Bridge, furnished by Riverside Water Co., include San Timoteo Creek and Redlands Wash, but do not show diversions by Gage canal at Sterling Street.

Discharge measurements of Santa Ana River at San Bernardino, Cal., during January, 1916.

[Made by H. B. Andrews.]

Date.	Discharge.	Time of measurement.	Date.	Discharge.	Time of measurement.
	Sec.-ft.			*Sec.-ft.*	
Jan. 6	127	3.50 p. m.	Jan. 22	730	2.15 p. m.
20	1,106	4.15 p. m.	28	3,725	12.35 p. m.

LYTLE CREEK AT SAN BERNARDINO, CAL.

The following table was compiled from a blue-print hydrograph furnished by J. A. Sourwine, county engineer. This hydrograph was determined from measurements of East and West channels of Lytle Creek. The West channel was measured at the new Fourth Street Bridge until it went out at 8.05 a. m. January 18. Later measurements were made at the Atchison, Topeka & Santa Fe Railway bridge, at North Colton. The East channel was measured at the old Fourth Street Bridge until about 9 a. m. January 18, and later at Mount Vernon Avenue Bridge. The discharge record given in the table was taken from the hydrograph at points where there was a change in curvature. A planimeter was used to determine mean daily discharge.

Discharge, in second-feet, of Lytle Creek at San Bernardino, Cal., for January, 1916.

Date.	Time.	Discharge.	Mean daily discharge.		
			East channel.	West channel.	Total.
Jan. 16	10.00 p. m.	Dry.			
17	3.00 a. m.	650	920	4,320	5,240
	7.30 a. m.	6,200			
	10.00 a. m.	13,400			
	12.45 p. m.	6,200			
	3.30 p. m.	8,500			
	11.00 p. m.	2,650			
Jan. 18	5.00 a. m.	8,000			6,640
	9.40 a. m.	16,000			
	1.00 p. m.	8,000			
	4.30 p. m.	2,800			
Jan. 19	10.00 a. m.	550			
	5.00 p. m.	350			

SAN JACINTO RIVER NEAR SAN JACINTO, CAL.

LOCATION.—In sec. 20, T. 5 S., R. 2 E., at Oak Cliff, 1 mile above mouth of North Fork of San Jacinto River and 10 miles southeast of San Jacinto, Riverside County.

DRAINAGE AREA.—108 square miles (measured on topographic map).

ELEVATION.—About 2,200 feet above sea level.

MAXIMUM DISCHARGE IN JANUARY, 1916.—Mr. W. S. Post, consulting engineer, measured cross section and slope at this point and estimated the crest discharge as follows: Area, 2,058 square feet; wet perimeter, 392 feet; hydraulic radius, 5.2; slope, 0.029; discharge, 30,000 second-feet or 278 second-feet per square of drainage area.

SAN JACINTO RIVER NEAR ELSINORE, CAL.

LOCATION.—Near center of sec. 9, T. 6 S., R. 4 W., at A. T. & S. F. Ry. bridge at Elsinore Junction, about 1½ miles above junction with Elsinore Lake (low-water stage), and 1½ miles southeast of Elsinore, Riverside County.

DRAINAGE AREA.—718 square miles (measured on topographic maps).

ELEVATION.—About 1,250 feet above sea level.

RECORDS AVAILABLE.—January 1 to 31, 1916.

GAGE.—Vertical staff fastened to trestle bent of railway bridge near left bank; read daily.

DISCHARGE MEASUREMENTS.—Made from railway bridge or by wading.

CHANNEL AND CONTROL.—Composed of gravel and small boulders; fairly permanent.

MAXIMUM DISCHARGE IN JANUARY, 1916.—Measurements of cross section and slope were made March 9 in the canyon about three-fourths mile above gaging station at railway bridge. The channel at this point is composed of sand and gravel with a few small boulders and is straight. Along the banks of the low-water channel there are small bushes and a few trees. There is but one channel at all stages and the high-water banks are clean (Pl. XVII, *A*). The slope of the water surface at maximum stage was determined for a distance of 1,150 feet. The crest discharge has been computed as follows: Width, 290 feet; wet perimeter, 295 feet; area, 1,730 square feet; hydraulic radius, 5.9; slope of water surface (flood stage), 0.0033. If the value of n in Kutter's formula is assumed as 0.035, the discharge is 14,000 second-feet, or 195 second-feet per square mile of drainage area (drainage area at this point, 717 square miles measured on topographic maps). This discharge occurred January 28 at 11 a. m., gage height 19.0 feet.

ACCURACY.—Gage height record affected by backwater from Elsinore Lake beginning January 30. Rating curve defined by two medium-stage measurements and maximum of flood discharge computed from cross-section and slope. Gage read once a day to hundredths feet. Results fair.

Daily discharge, in second-feet, of San Jacinto River near Elsinore, Cal., for January, 1916.

Date.	Discharge.	Date.	Discharge.	Date.	Discharge.	Date.	Discharge.
Jan. 1	2	Jan. 9	3	Jan. 17	730	Jan. 25	730
2	2	10	3	18	830	26	580
3	2	11	3	19	1,750	27	1,010
4	2	12	2	20	6,800	28	14,000
5	2	13	2	21	1,750	29	6,800
6	2	14	2	22	1,010	30	1,750
7	2	15	2	23	580	31	1,350
8	2	16	2	24	680		

Total run-off for month	acre-feet	79,900
	depth in inches on drainage area	2.09

Discharge measurements of San Jacinto River near Elsinore, Cal., during January, 1916.

[Made by F. C. Ebert.[

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Jan. 25	10.40	680
26	10.32	651

HISTORY OF ELSINORE LAKE.[1]

Apparently the earliest specific reference to the amount of water in Elsinore Lake is contained in the notes of a traveler through southern California about 1810, who mentions "Laguna Grande," the original Mexican name for the lake, as being little more than a swamp about a mile long. For the period between that time and 1862 data as to its rise and fall are not available, but in 1862 it was very high and probably overflowed. During the succeeding dry period, especially during the years 1866 and 1867, when practically no rain fell on the drainage area tributary to the lake, it receded very rapidly but was full again in 1872 and overflowed down its outlet through Temescal Canyon. After this it again evaporated to a level probably as low as it has ever been since, but the great rains of the winter of 1883–84 filled it to overflowing in three weeks.

Americans had settled around it by this time and their descriptions of conditions say that large willow trees surrounding the low-water shore line were of such size that they must have been thirty or more years old. The rainfall in the next ten years was excessive, and the lake stayed high and overflowed naturally during three or four years of the decade. It was purchased by the Temescal Water Co. for the irrigation of lands at Corona, Cal., and its outlet channel was deepened, permitting gravity flow to Corona for a year or more after the lake level had sunk below the elevation of its outlet. As the surface still receded a pumping plant was installed and the water was raised a maximum of about 10 feet and then flowed down the natural channel of Temescal Canyon. Pumping was continued a couple of seasons, but the concentration of salts in the lake, due to the evaporation and low rainfall, soon made the water unfit for irrigation.

After 1893 the water level sank almost continuously for nearly ten years, with, of course, a slight rise every winter. The heavier precipitation, beginning in 1903, gradually filled the lake to about half the depth between its minimum level since 1883 and its high level or overflow point. The flood of January, 1916, rapidly raised the level, to overflowing, although the run-off from its drainage area into the lake appears to have been considerably less than that of the wet years of 1883–84 and 1888–89. (See Pl. XVII, *B*.)

[1] Prepared by Francis R. Schanck, assistant inspector of irrigation, United States Indian Office, Los Angeles, Cal.

The fact that large trees were growing 20 feet or more below the high-water level when the lake filled in 1883–84 indicates that the high water of the sixties and seventies must have been of very short duration. The stumps of the trees were still visible in 1888 and 1889 many hundred feet from shore, but by the time the lake receded in the middle nineties these had disappeared.

ELSINORE LAKE AT ELSINORE, CAL.

LOCATION.—In La Laguna grant at outlet of lake at Elsinore, Riverside County.

GAGE.—Vertical staff installed December 1, 1915; datum 1,237.20 feet above sea level. The water surface rose above this gage and a new staff was installed January 25, 1916; datum 1,237.53 feet. This gage was flooded and the observer installed a temporary staff on January 30, 1916, at approximately the same datum, but before it could be referred to previous datum it also was flooded.

Daily elevation, in feet above sea level, of Elsinore Lake at Elsinore, Cal., for January, 1916.

Date.	Elevation.	Date.	Elevation.	Date.	Elevation.	Date.	Elevation.
Jan. 1	1,245.4	9	1,245.4	17	1,246.7	24	1,252.9
2	1,245.3	10	1,245.4	18	1,247.2	25	1,253.2
3	1,245.3	11	1,245.4	19	1,248.7	26	1,254.0
4	1,245.3	12	1,245.4	20	1,250.2	27	1,254.5
5	1,245.3	13	1,245.4	21	1,251.2	28	1,255.5
6	1,245.3	14	1,245.4	22	1,252.2	29	1,257.5
7	1,245.3	15	1,245.4	23	1,252.7	30	1,258.5
8	1,245.3	16	1,245.4				

SOUTH FORK OF SAN JACINTO RIVER AT HEMET RESERVOIR, NEAR SAN JACINTO, CAL.

LOCATION.—The dam is in sec. 7, T. 6 S., R. 3 E., below Hemet Valley, about 6 miles above mouth of South Fork of San Jacinto River, and 17 miles southeast of San Jacinto, Riverside County.

DRAINAGE AREA.—65.8 square miles (at dam; measured on topographic map).

ELEVATION.—About 4,350 feet above sea level.

DISCHARGE.—The following table, computed by Mr. W. S. Post, consulting engineer, shows the run-off into Hemet reservoir.

Gage height, in feet, and discharge, in second-feet, of South Fork of San Jacinto River at Hemet reservoir, near San Jacinto, Cal., for January, 1916.

Date.	Time.	Reservoir gage height.	Instantaneous discharge into reservoir.	Mean daily discharge.	Date.	Time.	Reservoir gage height.	Instantaneous discharge into reservoir.	Mean daily discharge.
Jan. 14	8 a. m.	116.65	22	54	22	8 a. m.	122.5	146	146
15	8 a. m.	116.88	39	42	23	8 a. m.	122.5	146	146
16	8 a. m.	117.17	137	164	24	8 a. m.	122.5	162	176
17	2 p. m.	119.17	2,810	1,450	25	8 a. m.	122.67	228	190
	6 p. m.	124.5	3,200	.....	26	8 a. m.	122.67	212	212
	12 p. m.	125.83	1,440	.....	27	8 a. m.	[a] 122.67	1,710	5,070
18	8 a. m.	124.5	822	754		4 p. m.	128.0	9,550	.....
	8 p. m.	123.67	930	.....	28	8 a. m.	125.0	2,460	2,880
	12 p. m.	[a] 123.5	748	.....	29	8 a. m.	123.92	1,300	1,390
19	12 p. m.	[a] 122.67	88	412	30	8 a. m.	123.83	1,180	980
20	8 a. m.	122.5	100	126	31	8 a. m.	122.92	260	349
21	8 a. m.	122.5	146	146					

[a] Interpolated.

Total run-off for period { acre-feet 29,100
depth in inches on drainage area 8.30

NOTE.—Table summarizes the detailed computations, based on notes furnished by the water company and covering stage of reservoir, spillway discharge, gate leakage, and other conditions.

SAN GABRIEL RIVER BASIN.

GENERAL FEATURES.

San Gabriel River is one of the three large streams traversing the valley of southern California. Its drainage basin lies wholly in Los Angeles County west of the Santa Ana basin and east of the Los Angeles basin and stretches from the crest of the Sierra Madre to the Pacific, a distance of about 50 miles. Its total drainage area is approximately 700 square miles, about one-third of which consists of mountain slopes, which contribute practically all of the run-off except in heavy storms. The remaining two-thirds is embraced in the San Gabriel Valley at the base of the mountains and in the coastal plain southeast of the city of Los Angeles.

The mountainous part of the basin is somewhat rectangular. Its length east and west is about 25 miles, and its width about 10 miles. It lies on the southern slope of the Sierra Madre opposite the basins of Big and Little Rock creeks at the north and on the southern slope of the San Gabriel Range, through which the river breaks near Azusa and enters the San Gabriel Valley.

The main stream is formed by the junction of two principal forks, one from the north and east and the other from the west. Each of the branches receives many tributaries from the crests of the surrounding ranges. The headwaters come from the western slope of San Antonio Peak (Old Baldy), altitude 10,080 feet, and from the southern slope of other high peaks at the north, such as North Baldy and Islip mountains. The west fork drains the northern slope of Mount Wilson, the eastern and northern slopes of San Gabriel Peak, and a portion of the southern slopes of the main range to the north. It joins the main stream about 8 miles above the mouth of the canyon. The general course of the stream is southwestward. After leaving the mountains it traverses San Gabriel Valley in a wide wash of sand, gravel, and boulders, then breaks through the range of foothills separating San Gabriel Valley from the coastal plain at a point called The Narrows, about 5 miles northwest of Whittier, and enters the coastal plain, across which it flows to its mouth in Alamitos Bay, a few miles east of Long Beach. The total length of the stream is about 65 or 70 miles.

The principal tributaries of San Gabriel River are Fish Fork and Cattle Creek from the east, and Iron and West forks from the west.

Altitudes in San Gabriel basin range from 20 to 200 feet on the Coastal Plain from 200 to 900 feet in San Gabriel Valley, and from 1,000 to 10,000 feet in the mountains. The range of foothills near Whittier has an altitude of about 1,250 feet. The topography is rough and rugged in the mountains, especially in the upper part, where deep and narrow canyons exist. The geologic formation is

granitic, with a light soil covering. The San Gabriel Valley is more or less rolling and is composed of granitic wash from the mountains.

The basin is rather poorly forested, having a sparse timber growth on the higher slopes and brush with some scattered timber on the middle and lower elevations.

The mean annual precipitation in this basin ranges from 15 to 20 inches in the valley area, and from 20 to 40 inches in the mountains. It occurs almost entirely as rain except on the higher peaks, where snow falls during the winter. On the northern slopes snow remains for several weeks.

SAN GABRIEL RIVER NEAR AZUSA, CAL.

LOCATION.—In the NW. ¼ sec. 23, T. 1 N., R. 10 W., near road crossing at mouth of canyon, about half a mile above the Pacific Light & Power Corporation's power house and 2 miles north of Azusa, Los Angeles County.

DRAINAGE AREA.—222 square miles.

ELEVATION.—About 750 feet above sea level.

RECORDS AVAILABLE.—1894 to January 31, 1916.

GAGE.—Staff were fastened to rock point on left bank about 200 feet above ford, read daily; oftener during floods. Gage used January 2 to 8 and 12 to 16, 1916, is on left bank about 600 feet below ford at an independent datum.

DISCHARGE MEASUREMENTS.—Made from cable 1,000 feet above ford or by wading near gage. The float measurements on January 17 and 18, 1916, were made just below gage. The cross-section for these measurements, secured March 8, 1916, was taken 145 feet below regular gage (Pl. XVI, *B*, p. 68).

CHANNEL AND CONTROL.—Composed of gravel and boulders; shifts during high water.

EXTREMES OF DISCHARGE.—1894–1915: Maximum stage recorded, 11.7 feet February 20, 1914 (discharge, 18,100 second-feet); minimum stage, dry for several months during each year.

MAXIMUM DISCHARGE IN JANUARY, 1916.—The crest of the flood occurred at 7 a. m., January 18; gage height, 12.0 feet (discharge, 40,000 second-feet).

DIVERSIONS.—The power canal of the Pacific Light & Power Corporation heads about 5 miles above the station. No water in this canal from afternoon of January 17 to the morning of January 19, as the intake was closed by drift.

REGULATION.—None.

ACCURACY.—Results considered good for January, 1916. Rating curves for extreme high water are defined by the float measurements made January 17 and 18. A coefficient of 0.80 was used to reduce float velocities to mean velocities. There was doubtless a fill in the channel after the crest of the flood on January 18 and hence the areas for the float measurements are probably low.

Discharge measurements of San Gabriel River near Azusa, Cal., for January, 1916.

[Made by F. C. Ebert.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Jan. 3	[a] 1.82	63	Jan. 15	[a] 2.08	117	Jan. 19	7.10	3,750
4	[a] 1.62	39	17	10.30	[b] 18,400	20	6.62	2,380
12	[a] 2.03	107	18	11.50	[b] 32,400	21	6.34	1,570
13	[a] 1.88	76	19	7.38	4,300	24	5.80	848

[a] Gage below ford read. [b] Float measurements.

Combined daily discharge, in second-feet, of San Gabriel River and Pacific Light & Power Corporation's canal near Azusa, Cal., for January, 1916.

Date.	Discharge.	Date.	Discharge.	Date.	Discharge.	Date.	Discharge.
Jan. 1	63	9	480	Jan. 17	17,100	Jan. 25	840
2	93	10	820	18	22,300	26	700
3	159	11	480	19	3,980	27	7,940
4	117	12	190	20	2,450	28	4,290
5	179	13	159	21	1,650	29	2,240
6	142	14	135	22	1,410	30	2,080
7	117	15	215	23	1,250	31	1,790
8	102	16	179	24	928		

Total run-off for month { acre-feet 148,000
depth in inches on drainage area 12.57

NOTE.—Water began flowing in river at gaging station on Jan. 2; discharge Jan. 17 and 18 computed from several gage readings.

LOS ANGELES RIVER BASIN.

GENERAL FEATURES.

Los Angeles River is formed by Tujunga, Pacoima, and other small creeks whose sources lie in the Sierra Madre northeast of the city of Los Angeles. These streams leave the mountains at a point about 25 miles above the city and enter the comparatively flat country of the San Fernando Valley, where, except at times of excessive flood, the waters disappear in the sand and gravel washes. At the lower end of this valley is a secondary range of hills, extending from east to west, and bed rock obstruction forces the waters to the surface to form what is known as Los Angeles River. Below this point the river flows through the flat country of the Los Angeles Valley and enters the Pacific near the town of Long Beach. At the city of Los Angeles it is joined by Arroyo Seco. This stream issues from the mountains on the west side of Pasadena Mesa, and passes through an opening in a granite spur known as Devils Gate. Between the point where it leaves the mountain and Devils Gate lies a broad river bottom, 2 miles long, composed of coarse material, into which the water sinks rapidly. In passing over this material the volume of flood water is diminished.

LOS ANGELES RIVER AT LOS ANGELES, CAL.[1]

Los Angeles River was measured at the bridge near the old pigeon farm above junction with Arroyo Seco. The discharge at 11 a. m. January 19, 1916, was 1,308 second-feet. The maximum height of the flood during the storm was ascertained from an eye witness and from marks on the bank, as 4 feet higher than the stage of the river at the time the measurement was made. A velocity of 11.0 feet per second was used for computing the probable maximum discharge. The estimated maximum flow for the stream at this point was 7,268 second-feet.

[1] Lippincott, J. B., memorandum concerning the floods of Jan. 17 and 18, 1916.

The following is a summary of measurements made January 18, 1916, for the flood flow between Dominguez Junction and Cerritos, of the water entering the Los Angeles and Long Beach harbors:[1]

	Second-feet.
Main Cerritos bridge	22,873
Cota bridge (first opening to the west)	1,816
At pole No. 1006 (second opening)	676
Bridge No. 1463	1,057
Bridge No. 1450	978
Bridge No. 1433	3,240
Bridge No. 1418	233
Compton Creek	240
Total	31,113

Practically half the flow was going to the east into the Long Beach Harbor and, as near as could be determined from the observations, half to the west into Wilmington Harbor. It is considered that the 1916 flood at this point was as great in volume as in 1914 and that it lasted longer.

ARROYO SECO NEAR PASADENA, CAL.

LOCATION.—Near south line of sec. 30, T. 2 N., R. 12 W. (unsurveyed), just below trail crossing at forest ranger's station in Angeles National Forest, about 3 miles above Devils Gate, 1½ miles above mouth of Millard Canyon, and 5½ miles northeast of Pasadena, Los Angeles County.

DRAINAGE AREA.—16.4 square miles (measured on topographic maps).

ELEVATION.—About 1,450 feet above sea level.

RECORDS AVAILABLE.—December 1, 1910, to January, 1916.

GAGE.—Staff fastened to an alder on right bank 300 feet southeast of ranger's station.

DISCHARGE MEASUREMENTS.—Made by wading below gage or from foot log.

CHANNEL AND CONTROL.—Composed of solid rock, gravel, and boulders; slightly shifting during high water.

EXTREMES OF DISCHARGE.—1910–1915: Maximum stage recorded, 12.5 feet February 20, 1914 (discharge, 5,630 second-feet); minimum stage, below gage September 12 to 23, 1913 (discharge estimate, 0.1 second-foot).

MAXIMUM DISCHARGE IN JANUARY, 1916.—Crest of flood occurred at 9.30 a. m. January 17; gage height, 9.3 feet; discharge, 3,150 second-feet, or 192 second-feet per square mile.

ACCURACY.—Gage read only 5 days in January. The high-water extension of the rating curve is based on measurement of slope and cross section of the channel. Curve well defined for medium and low stages.

Discharge measurements of Arroyo Seco near Pasadena, Cal., during January, 1916.

[Made by F. C. Ebert.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Jan. 12	3.55	14
22	4.18	64

[1] Lippincott, J. B., memoranda concerning the floods of Jan. 17 and 18, 1916.

Mean daily gage height, in feet, and discharge, in second-feet, of Arroyo Seco near Pasadena, Cal., for January, 1916.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
Jan. 17	7.65	[a] 1,930	Jan. 24	4.1	51
22	4.14	58	25	[a] 4.18	65
23	4.04	42			

[a] Maximum discharge Jan., 1916, see station description.

ARROYO SECO[1] AT LOS ANGELES, CAL.

On January 19, 1916, the flood flow of the Arroyo Seco was measured at Avenue 20 Bridge in Los Angeles. The peak of the flood had passed. Soundings were made from the bridge at intervals of 5 feet. The velocity was ascertained by means of floats and found to be 6.0 feet per second. The discharge at 9.30 a. m. January 19, 1916, was 737 second-feet. From the statement of an eye witness and from water marks on the banks it was found that at the crest of the flood on the preceding days the water had been 4 feet higher than at the time of measurement. Accordingly, a section was computed for this higher level. The velocity at the higher stage was estimated to be 11.0 feet per second, which gives a maximum discharge for the storm at this point of 6,215 second-feet.

SANTA CLARA RIVER BASIN.

GENERAL FEATURES.

Santa Clara River has its source in Soledad Canyon in the north-central part of Los Angeles County. Its general course is westward, and it enters the Pacific Ocean about 3 miles southeast of Ventura. The principal tributaries are Castac, Piru, Sespe, and Santa Paula creeks, which enter from the north. During the low-water period the channels of these streams are usually dry at their junction with the main stream. For the lower 40 miles of its course the channel of Santa Clara River is broad and sandy. During the rainy season it is subject to very sudden and severe floods while for the remainder of the year the channel is practically dry.

SESPE CREEK NEAR SESPE, CAL.

LOCATION.—At Bradfields Camp, in Santa Barbara National Forest, three-fourths of a mile below mouth of West Fork of Sespe Creek, 4½ miles above intake of Fillmore canal, and about 6½ miles northwest of Sespe, Ventura County

DRAINAGE AREA.—216 square miles (measured by Ralph Bennett, consulting engineer).

ELEVATION.—About 1,350 feet above sea level.

GAGE.—Painted on large boulder and on rock cliff on left bank.

DISCHARGE MEASUREMENTS.—Made from cable 250 feet above gage or by wading.

[1] Lippincott, J. B., memoranda concerning the floods of Jan. 17 and 18, 1916.

CHANNEL AND CONTROL.—Gravel and large boulders; fairly permanent.

MAXIMUM DISCHARGE IN JANUARY, 1916.—The maximum stage reported was 18.7 feet (discharge 18,600 second-feet) on January 17 (time not given).

ACCURACY.—Results considered good. Discharge measurements made after January 17 show that the high water caused a small amount of scour in the channel. Rating curves well defined.

COOPERATION.—The gage-height record and discharge measurements were furnished by Sespe Light & Power Co.

Discharge measurements of Sespe Creek near Sespe, Cal., for January, 1916.

[Made by G. H. Killgore.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Jan. 2	7.60	508	Jan. 17	15.90	[a] 10,100	Jan. 19	9.20	1,550
3	6.70	292	17	18.70	[a] 17,400	21	7.60	678
4	8.90	1,320	18	16.90	[a] 13,700	27	12.90	[a] 4,690

[a] Float measurement; coefficient of 0.85 used to reduce surface velocities to mean velocities.

Mean daily discharge, in second-feet, of Sespe Creek near Sespe, Cal., for January, 1916.

Date.	Discharge.	Date.	Discharge.	Date.	Discharge.	Date.	Discharge.
Jan. 1	46	Jan. 9	850	Jan. 17	8,100	Jan. 25	360
2	605	10	440	18	11,400	26	345
3	560	11	205	19	2,320	27	6,500
4	960	12	144	20	1,060	28	1,360
5	184	13	119	21	615	29	900
6	144	14	480	22	495	30	705
7	110	15	228	23	390	31	595
8	106	16	253	24	375		

Total run-off for month	acre-feet	81,200
	depth in inches on drainage area	7.04

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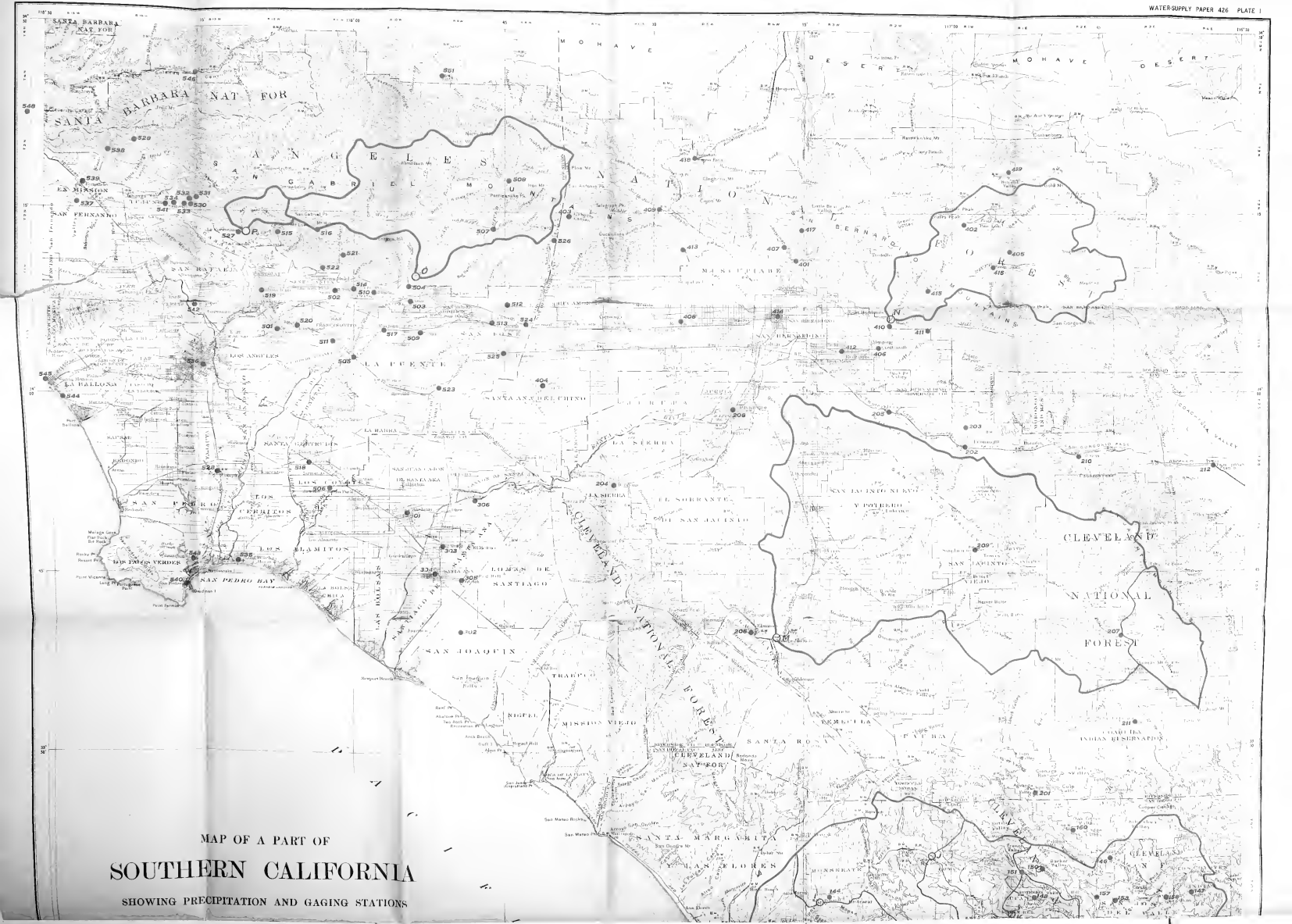
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SAN JACINTO
SAN JACINTO MOUNTAINS
SAN JACINTO VALLEY
LA HABRA
LA SIERRA
LA BALLONA
SAN JUAN CAPISTRANO
SAN JUAN CAPISTRANO
SAN MATEO CANYON
SAN MATEO POINT
SAN MATEO CREEK
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1917

Gaging station

Precipitation station

Boundaries of major and minor drainage basins

GAGING STATIONS

Letter	Station
A	Sweetwater River near Descanso
B	San Diego River at San Diego
C	San Diego River near Santee
D	San Dieguito River near Bernardo
E	Santa Ysabel Creek near Ramona
F	Santa Ysabel Creek near Mesa Grande
G	Santa Maria Creek near Ramona
H	San Luis Rey River at Oceanside
I	San Luis Rey River at Bonsall
J	San Luis Rey River near Pala
K	San Luis Rey River near Nellie
L	San Luis Rey River near Mesa Grande
M	San Jacinto River near Elsinore
N	Santa Ana River near Mentone
O	San Gabriel River near Azusa
P	Arroyo Seco near Pasadena

PRECIPITATION STATIONS

SAN DIEGO COUNTY

No. on map	Station	River basin
101	Barrett dam	Tia Juana River basin
102	Campo	Do
103	Marena reservoir	Do
104	Dulzura Summit	Otay River basin
105	Jamul ranch	Do
106	Jamul store	Do
107	Lower Otay reservoir	Do
108	Alpine Heights	Sweetwater River basin
109	Bonita	Do
110	Descanso	Do
111	Descanso ranger station	Do
112	Green Valley	Do
113	Sweetwater dam	Do
114	Boulder Creek	San Diego River basin
115	Chocolate	Do
116	Cuyamaca, East	Do
117	Cuyamaca reservoir	Do
118	Diverting dam	Do
119	El Cajon	Do
120	El Cajon, Sweetwater Pass	Do
121	Grossmont	Do
122	Julian	Do
123	Lakeside	Do
124	La Mesa reservoir	Do
125	Los Coches	Do
126	Miramar ranch	Do
127	Pine Hills	Do
128	Point Loma	Do
129	San Diego	Do
130	Stallings ranch	Do
131	Carroll dam site	San Dieguito River basin
132	Escondido	Do
133	Mesa Grande (Angel)	Do
134	Mesa Grande (Davis)	Do
135	Pamo dam site	Do
136	Ramona (Sentinel)	Do
137	Rose Glen	Do
138	San Pasqual	Do
139	Santa Ysabel divide	Do
140	Santa Ysabel ranch house	Do
141	Santa Ysabel store	Do
142	Volcan Mountain	Do
143	Witch Creek	Do
144	Canfield ranch (Bonsall)	San Luis Rey River basin
145	Damron	Do
146	Deadmans Hole	Do
147	Eagles Nest	Do
148	La Jolla Indian Reservation	Do
149	Matagual	Do
150	Mendenhall	Do
151	Nellie	Do
152	Oceanside	Do
153	Puerta La Cruz	Do
154	Valley Center	Do
155	Warner dam	Do
156	Warner ranch house	Do
157	Warner ranch (Rincon)	Do
158	Warner springs	Do
159	Warner's summer road	Do
160	Oak Grove	Temecula Creek basin
161	San Felipe	Great Basin
162	Gopher Canyon (Bonsall)	San Luis Rey River basin
163	San Luis Rey	Do

RIVERSIDE COUNTY

No. on map	Station	River basin
201	Aguanga	Temecula Creek basin
202	Beaumont	Santa Ana River basin
203	Beaumont (near)	Do
204	Corona	Do
205	El Casco	Do
206	Elsinore	Do
207	Hemet Lake	Do
208	Riverside	Do
209	San Jacinto	Do
210	Cabezon	Great Basin
211	Coahuila	Do
212	Palm Springs	Do

ORANGE COUNTY

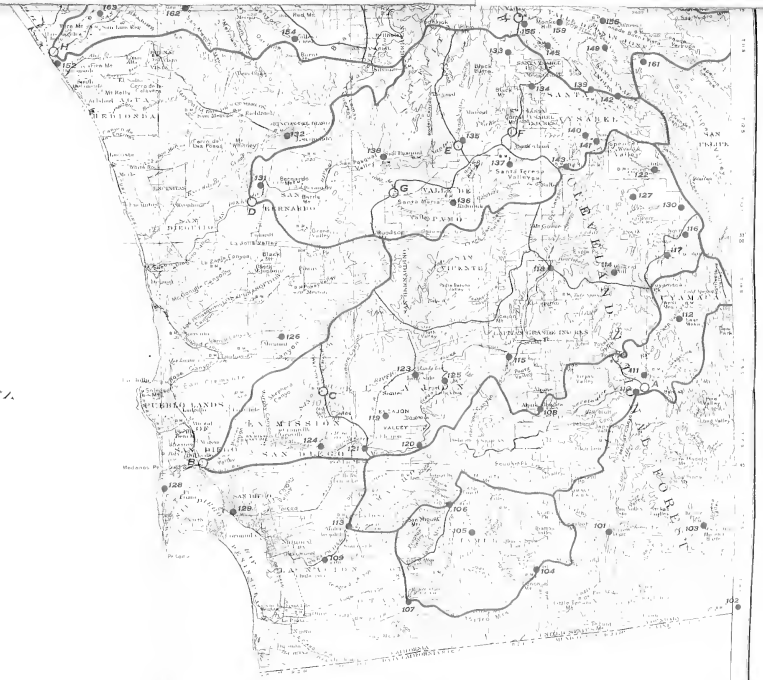
No. on map	Station	River basin
301	Anaheim	Santa Ana River basin
302	Old Ranch	Do
303	Orange	Do
304	Santa Ana	Do
305	Tustin	Do
306	Yorba Linda	Do

SAN BERNARDINO COUNTY

No. on map	Station	River basin
401	Arrowhead Springs	Santa Ana River basin
402	Bear Valley dam	Do
403	Camp Baldy	Do
404	Chino	Do
405	Converse Nursery	Do
406	Crafton-ville	Do
407	Dormans ranch	Do
408	Fontana	Do
409	Glenn ranch	Do
410	Mentone power house	Do
411	Mill Creek No. 2	Do
412	Redlands	Do
413	Rialto (Lytle Creek)	Do
414	San Bernardino	Do
415	Santa Ana River	Do
416	Seven Oaks	Do
417	Squirrel Inn	Do
418	Summit No. 2 (Cajon Pass)	Do
419	Holcomb	Great Basin

LOS ANGELES COUNTY

No. on map	Station	River basin
501	Alhambra	San Gabriel River basin
502	Argadia	Do
503	Arrow	Do
504	Azusa power house	Do
505	Bassett	Do
506	Burno Park	Do
507	Camp Bonita	Do
508	Camp Iron Fork	Do
509	Covina	Do
510	Duarte	Do
511	El Monte	Do
512	Livernak Canyon	Do
513	Lundsburg	Do
514	Monrovia	Do
515	Mount Lowe	Do
516	Mount Wilson	Do
517	Baldwin Acres	Do
518	Norwalk	Do
519	Pasadena	Do
520	San Gabriel	Do
521	Santa Anita ranger station	Do
522	Sierra Madre	Do
523	Walnut	Do
524	Claremont	Santa Ana River basin
525	Pomona	Do
526	Sierra power house	Do
527	Arroyo Seco ranger station	Los Angeles River basin
528	Compton	Do
529	Dillon ranch	Do
530	Empire Canyon	Do
531	Grassy Flat	Do
532	Haynes Camp	Do
533	Haynes Canyon (mouth)	Do
534	Littlelands	Do
535	Long Beach	Do
536	Los Angeles	Do
537	Oneonta ranch	Do
538	Pacoima	Do
539	San Fernando	Do
540	San Pedro	Do
541	Sunland	Do
542	Tropico	Do
543	Wilmington	Do
544	Ocean Park	Coast Basin
545	Santa Monica	Do
546	Ravenna	Santa Clara basin
548	Newhall	Do
551	Valyermo	Great Basin



Base from U. S. Geological Survey map of Southern California, Sheets 1 and 2

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